Tape or Staple Here

ROBOTICS DESIGN SYSTEM

Place
Stamp
Here

Innovation One, Inc.
350 North Henderson
Fort Worth, Texas 76102

This side out

(Fold Here)

ROBOTICS DESIGN SYSTEM

Think. Create. Build. Amaze. Vex.

Tape or Staple Here

v.5 VEX™

ROBOTICS DESIGN SYSTEM

Vex™ values the creativity and contributions of our inventors. Join the community of Vex inventors by filling out this registration card, or you can register online, at: www.vexrobotics.com/register.

If you are under 18, your parent or guardian must sign this registration card, approving the release of your personal information.

Parent's Name:______________________________

Signature:______________________________

My child is under 18 years of age and I agree to the release of the personal information requested on this registration card.

First Name:______________________________

Last Name:______________________________

Address:______________________________

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City:______________________________

State/Province:______________ ZIP Code:____________

Country:______________________________

Comments/Suggestions

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Innovation One, Inc.
350 North Henderson
Fort Worth, TX 76102

OPTIONAL

Please tell us more about the Vex inventor:

Birth Date: __________(MM/DD/YY)

Gender: ☐ Male ☐ Female

What kind of inventor are you?

☐ Student ☐ Educator ☐ Hobbyist

What level of education has the inventor completed?

☐ 6th grade ☐ 8th grade ☐ 12th grade
☐ 2 year degree ☐ 4 year degree ☐ Postgraduate
☐ Vocational/Technical degree (describe)____________________

This Vex Robotics Design System was...

☐ purchased by the inventor
☐ purchased as a gift for the inventor
☐ provided through a school/organizational curriculum/activity

How many video and PC based games did the inventor purchase/receive last year?

☐ none ☐ 1 5 ☐ 6 10
☐ 11 15 ☐ 16 or more

How did the inventor/purchaser learn about the Vex Robotics Design System?

☐ From a robotics club, competition, or activity
☐ Newspaper or magazine article or print ad
☐ Radio news story, talk show or commercial
☐ Television news story, talk show or commercial
☐ Online ad
☐ Display in a store

What programming skills/experience does the inventor have?

☐ none ☐ Java ☐ BASIC
☐ Visual BASIC ☐ C, C++ or Visual C ☐ Stamp
☐ HTML ☐ Other?____________________

In what types of media are the inventor interested?

☐ Magazines ☐ Newspapers ☐ Books
☐ Music videos / MTV ☐ Radio ☐ Television
☐ Internet ☐ Computer ☐ Other?__________

List the inventor's other interests and activities.

____

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____

____

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Vex Inventor's Guide

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Structure Subsystem 2.1

Motion Subsystem 3.1

Power Subsystem 4.1

Sensor Subsystem 5.1

Control Subsystem 6.1

Logic Subsystem 7.1

Programming Subsystem 8.1

Reference

The FCC Wants You to Know
This equipment has been tested and found to comply with the limits for radio controlled devices, pursuant to Part 15 and Part 95 of the *FCC Rules.* These limits are designed to provide reasonable protection against harmful interference. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Consult your local electronics store or an experienced radio/TV technician for help.
- If you cannot eliminate the interference, the FCC requires that you stop using your R/C transmitter.

Warning: Changes or modifications note expressly approved by Innovation One may cause interference and void the user's authority to operate the equipment. Only use authorized crystals designed for use with the Vex Robotics Design System RF Receiver.

Important: The EPA certified RBRC® Battery Recycling Seal on the nickel-cadmium (Ni-Cd) battery indicates Innovation One voluntarily participates in an industry program that collects and recycles NiCd batteries at the end of their useful life, when taken out of service in the United States or Canada. The RBRC program provides a convenient alternative to placing used Ni-Cd batteries into the trash or the municipal waste stream, which may be illegal in your area. Please call 1-800-8-battery for information on Ni-Cd battery recycling and disposal bans/restrictions in your area. Innovation One's involvement in this program is part of the company's commitment to preserving our environment and conserving our natural resources.

Limited 90-day Warranty
This product is warranted by Innovation One against manufacturing defects in material and workmanship under normal use for ninety (90) days from the date of purchase from authorized Innovation One dealers. For complete warranty details and exclusions, check with your dealer.

Innovation One, Inc.
350 North Henderson Street
Fort Worth, TX 76102

11/04

Printed in China

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The actual product may vary from images depicted in this Inventor's Guide.

welcome!

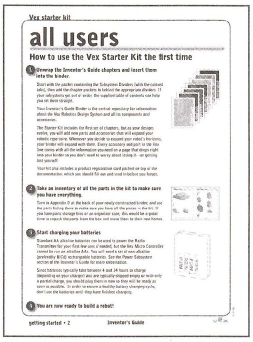
This Inventor's Guide is provided as part of the Vex Starter Kit as a tool to help you get started using your robot. Depending on how much experience you have had with robotics in the past, you will find different parts of this manual to be most useful.

Using this Guide

The Vex Robotics Design System supports open exploration by users of any skill level. Three "tracks" are described below that will help you to get started with the kit, based on the amount of experience you already have in the field of robotics.

All Users Track

Users old and new should start with the **ALL USERS** section, which covers material that both new and veteran users will need to get started.



Vex starter kit

all users

How to use the Vex Starter Kit the first time

1. Unwrap the Inventor's Guide chapters and insert them into the binder.

Start with the packet containing the Subsystem Dividers (with the colored tabs), then add the chapter packets in behind the appropriate dividers. If your subsystems get out of order, the supplied table of contents can help you set them straight.

Your Inventor's Guide Binder is the central repository for information about the Vex Robotics Design System and all its components and accessories.

The Starter Kit includes the first set of chapters, but as your designs evolve, you will add new parts and accessories that will expand your robotic repertoire. Whenever you decide to expand your robot's horizons, your binder will expand with them. Every accessory and part in the Vex line comes with all the information you need on a page that drops right into your binder so you don't need to worry about losing it—or getting lost yourself.

Your kit also includes a product registration card packed on top of the documentation, which you should fill out and send in before you forget.

2. Take an inventory of all the parts in the kit to make sure you have everything.

Turn to Appendix D at the back of your newly constructed binder, and use the parts listing there to make sure you have all the pieces in the kit. If you have parts storage bins or an organizer case, this would be a great time to unpack the parts from the box and move them to their new homes.

3. Start charging your batteries

Standard AA alkaline batteries can be used to power the Radio Transmitter for your first few uses if needed, but the Vex Micro Controller cannot be run on alkaline AAs. You will need a set of non-alkaline (preferably NiCd) rechargeable batteries. See the Power Subsystem section of the Inventor's Guide for more information.

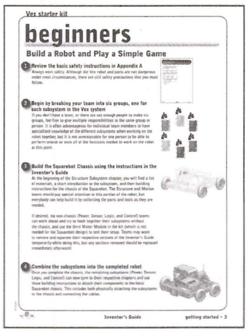
Since batteries typically take between 4 and 14 hours to charge (depending on your charger) and are typically shipped empty or with only a partial charge, you should plug them in now so they will be ready as soon as possible. In order to ensure a healthy battery charging cycle, don't use the batteries until they have finished charging.

4. You are now ready to build a robot!

getting started • 2 Inventor's Guide

Beginner Track

The **BEGINNERS** section is for users with a minimal amount of knowledge in the field of robotics to get up and running quickly, and to learn by doing, rather than being overwhelmed with technical information from the start. Exploration is encouraged if you would like to learn more about a particular area, but not required in order to complete the tasks.



Vex starter kit

beginners

Build a Robot and Play a Simple Game

1. Review the basic safety instructions in Appendix A

Always work safely. Although the Vex robot and parts are not dangerous under most circumstances, there are still safety precautions that you must follow.

2. Begin by breaking your team into six groups, one for each subsystem in the Vex system

If you don't have a team, or there are not enough people to make six groups, feel free to give multiple responsibilities to the same group or person. It is often advantageous for individual team members to have specialized knowledge of the different subsystems when working on the robot together, but it is not unreasonable for one person to be able to perform several or even all of the functions needed to work on the robot at this point.

3. Build the Squarebot Chassis using the instructions in the Inventor's Guide

At the beginning of the Structure Subsystem chapter, you will find a list of materials, a short introduction to the subsystem, and then building instructions for the chassis of the Squarebot. The Structure and Motion teams should pay special attention to this portion of the robot, but everybody can help build it by collecting the parts and tools as they are needed.

If desired, the non-chassis (Power, Sensor, Logic, and Control) teams can work ahead and try to hook together their subsystems without the chassis, and use the third Motor Module in the kit (which is not needed for the Squarebot design) to test their setup. Teams may want to remove and separate their respective sections of the Inventor's Guide temporarily while doing this, but any sections removed should be replaced immediately afterward!

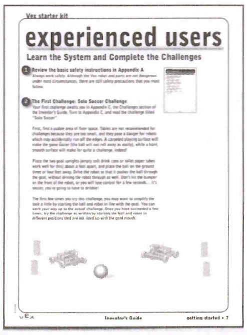
4. Combine the subsystems into the completed robot

Once you complete the chassis, the remaining subsystems (Power, Sensor, Logic, and Control) can now turn to their respective chapters and use those building instructions to attach their components to the basic Squarebot chassis. This includes both physically attaching the subsystems to the chassis and connecting the cables.

Inventor's Guide getting started • 3

Experienced Users Track

The **EXPERIENCED USER** section is for those who have worked with robots or in related fields in the past, especially those who have participated in FIRST competitions. The approach in this track is centered around tackling a simple challenge, and learning the particulars of the Vex system as you go, then moving on to more difficult challenges.



Vex starter kit

experienced users

Learn the System and Complete the Challenges

1. Review the basic safety instructions in Appendix A

Always work safely. Although the Vex robot and parts are not dangerous under most circumstances, there are still safety precautions that you must follow.

2. The First Challenge: Solo Soccer Challenge

Your first challenge awaits you in Appendix C, the Challenges section of the Inventor's Guide. Turn to Appendix C, and read the challenge titled "Solo Soccer".

First, find a usable area of floor space. Tables are not recommended for challenges because they are too small, and they pose a danger for robots which may accidentally run off the edges. A carpeted playing surface will make the game easier (the ball will not roll away as easily), while a hard, smooth surface will make for quite a challenge, indeed!

Place the two goal uprights (empty soft drink cans or toilet paper tubes work well for this) about a foot apart, and place the ball on the ground three or four feet away. Drive the robot so that it pushes the ball through the goal, without driving the robot through as well. Don't hit the bumper on the front of the robot, or you will lose control for a few seconds... it's soccer, you're going to have to dribble!

The first few times you try this challenge, you may want to simplify the task a little by starting the ball and robot in line with the goal. You can work your way up to the actual challenge. Once you have succeeded a few times, try the challenge as written by starting the ball and robot in different positions that are not lined up with the goal mouth.

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01/31/05

all users

How to use the Vex Starter Kit the first time

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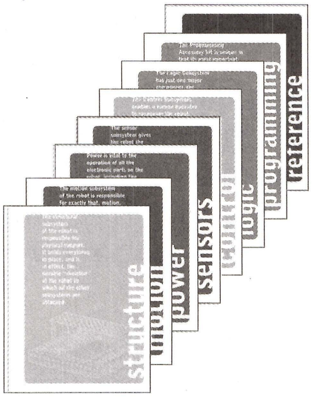

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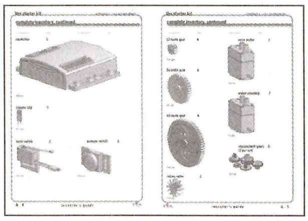

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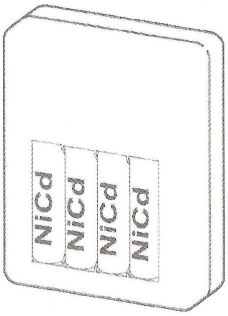
3 Start charging your batteries



Standard AA alkaline batteries can be used to power the Radio Transmitter for your first few uses if needed, but the Vex Micro Controller cannot be run on alkaline AAs. You will need a set of non-alkaline (preferably NiCd) rechargeable batteries. See the Power Subsystem section of the Inventor's Guide for more information.

Since batteries typically take between 4 and 14 hours to charge (depending on your charger) and are typically shipped empty or with only a partial charge, you should plug them in now so they will be ready as soon as possible. In order to ensure a healthy battery charging cycle, don't use the batteries until they have finished charging.

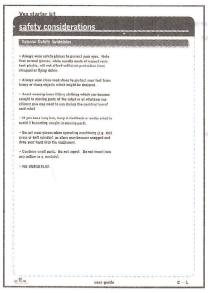
4 You are now ready to build a robot!

beginners

Build a Robot and Play a Simple Game

1 Review the basic safety instructions in Appendix A

Always work safely. Although the Vex robot and parts are not dangerous under most circumstances, there are still safety precautions that you must follow.



Vex starter kit

safety considerations

General Safety Guidelines

- Always wear safety glasses to protect your eyes. Note that normal glasses, while usually made of impact resistant plastic, will not afford sufficient protection from shrapnel or flying debris.
- Always wear close-toed shoes to protect your feet from heavy or sharp objects which might be dropped.
- Avoid wearing loose fitting clothing which can become caught in moving parts of the robot or of whatever machinery you may need to use during the construction of said robot.
- If you have long hair, keep it tied back or under a hat to avoid it becoming caught in moving parts.
- Do not wear gloves when operating machinery (e.g. drill press or belt grinder), as glove may become snagged and drag your hand into the machinery.
- Contains small parts. Do not ingest. Do not insert into any orifice (e.g. nostrils).
- NO HORSEPLAY.

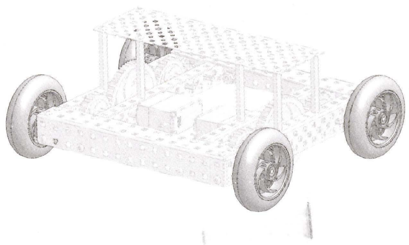
user guide C - 1

2 Begin by breaking your team into six groups, one for each subsystem in the Vex system

If you don't have a team, or there are not enough people to make six groups, feel free to give multiple responsibilities to the same group or person. It is often advantageous for individual team members to have specialized knowledge of the different subsystems when working on the robot together, but it is not unreasonable for one person to be able to perform several or even all of the functions needed to work on the robot at this point.

logic
structure
motion
control
sensors
power

3 Build the Squarebot Chassis using the instructions in the Inventor's Guide



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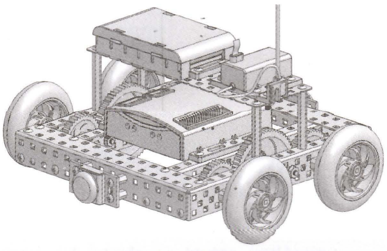
If desired, the non-chassis (Power, Sensor, Logic, and Control) teams can work ahead and try to hook together their subsystems without the chassis, and use the third Motor Module in the kit (which is not needed for the Squarebot design) to test their setup. Teams may want to remove and separate their respective sections of the Inventor's Guide temporarily while doing this, but any sections removed should be replaced immediately afterward!

4 Combine the subsystems into the completed robot

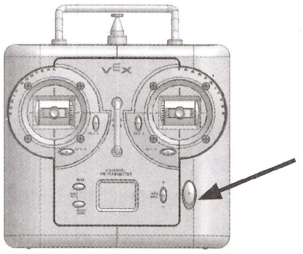


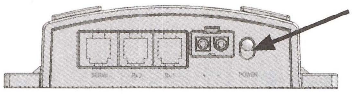
Once you complete the chassis, the remaining subsystems (Power, Sensor, Logic, and Control) can now turn to their respective chapters and use those building instructions to attach their components to the basic Squarebot chassis. This includes both physically attaching the subsystems to the chassis and connecting the cables.

beginners, continued

5 Test the robot

Once you have completed the robot, extend the antenna on the Radio Control Transmitter and turn it on by flipping the power switch on the front of the transmitter.

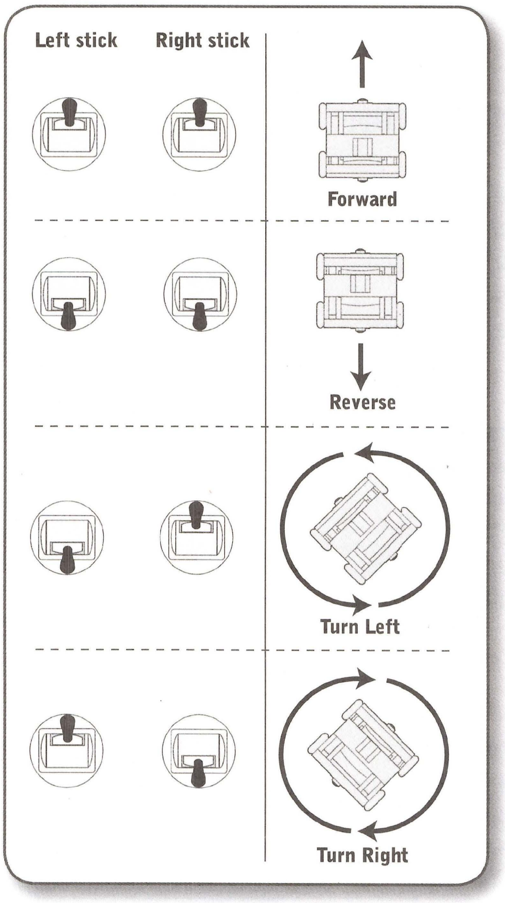




Once the Transmitter is on, you can turn on the Vex Micro Controller module on the robot by flipping its power switch (located next to the battery port).

You should see green lights for the Power Status and Rx1, and the large light blinking occasionally.

If you built and connected everything according to the instructions, you should now be able to drive the robot around using the sticks on your Radio Control Transmitter. The controls are as follows:



In addition, the bumper switch sensors on the front and rear of your robot are configured to act as "tag points." When they are hit by another robot or obstacle, your robot will be temporarily disabled.

beginners, continued

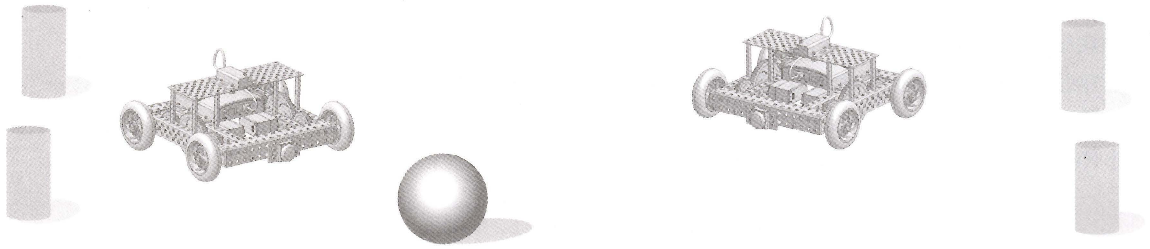
6 Solo Soccer Challenge

Your first challenge awaits you in Appendix C, the Challenges section of the Inventor's Guide. Turn to Appendix C, and read the challenge titled "Solo Soccer".

First, find a usable area of floor space. Tables are not recommended for challenges because they are too small, and they pose a danger for robots which may accidentally run off the edges. A carpeted playing surface will make the game easier (the ball will not roll away as easily), while a hard, smooth surface will make for quite a challenge, indeed!

Place the two goal uprights (empty soft drink cans or toilet paper tubes work well for this) about a foot apart, and place the ball on the ground three or four feet away. Drive the robot so that it pushes the ball through the goal, without driving the robot through as well. Don't hit the bumper on the front of the robot, or you will lose control for a few seconds... it's soccer, you're going to have to dribble!

The first few times you try this challenge, you may want to simplify the task a little by starting the ball and robot in line with the goal. You can work your way up to the actual challenge. Once you have succeeded a few times, try the challenge as written by starting the ball and robot in different positions that are not lined up with the goal mouth.



beginners, continued

7 Improve your Design

Just like with stock car racing, the generic all-purpose design of the Squarebot is a good starting point, but you can do much, much better! Think about how you might want to customize or "soup-up" your design to solve a problem. For example: Did you notice how difficult it was to get the ball to turn with the robot once it was moving? Can you think of any ways you might be able to fix that problem? Implement your solution and play the game again!

8 Challenges

When you're ready to move on to new, more challenging scenarios, turn to the challenges in Appendix C. Pick one of the other challenges there, and go for it! Formulate a strategy to accomplish the goals in the game, and implement your robotic solutions. As you plan and build your robot, consult the Inventor's Guide for background information about the components you have available, and refer to the Squarebot subsystems you built for ideas. Good luck!

9 Venture Forth

The Vex Robotics website provides a wealth of support and challenge ideas beyond the starter set supplied in this kit.

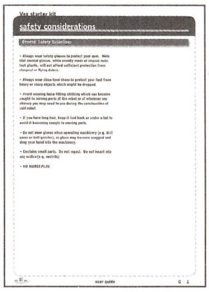
If you need a hand with your robot, or you want to learn about new accessories and challenges, visit http://www.vexrobotics.com.

Inventor's Guide Resources visited in this track:

- Safety in Appendix A
- Glossary in Appendix B
- Challenges from Appendix C
- Squarebot Parts & Assembly in each subsystem chapter
- The System Map poster included in the Starter Kit
- The Registration Card included in the Starter Kit

experienced users

Learn the System and Complete the Challenges



1 Review the basic safety instructions in Appendix A

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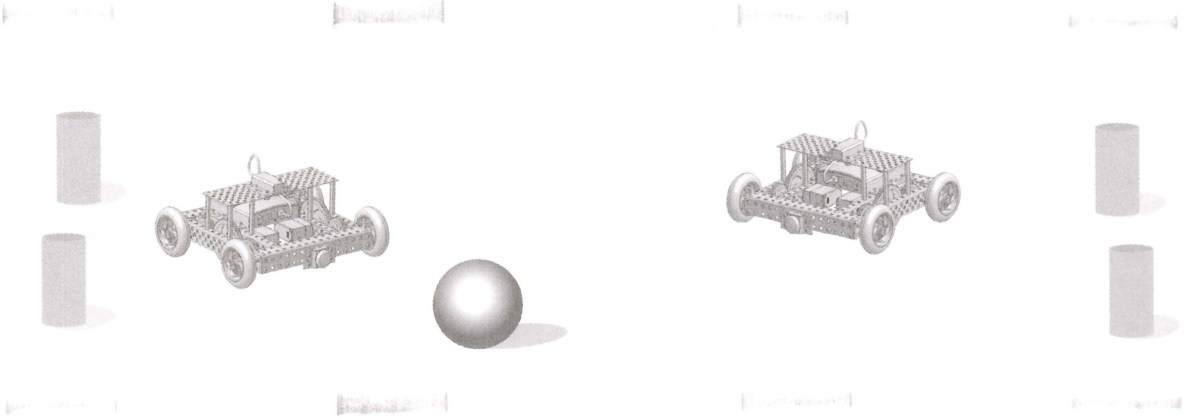


experienced users, continued

3 Design and Build a Robot to Play the Game

Your team must come up with a strategy and build a robot to play Solo Soccer. You may use any methods you like to organize your team efforts to plan and complete the robot, but a suggested method would be to break the team up into groups and assign responsibility for a few of the major robot subsystems to each group.

If you need ideas or assistance in the construction of any of the subsystems (Structure, Motion, Power, Sensors, Logic, or Control), flip to the appropriate section in the Inventor's Guide. You will find a variety of information there, from background information about the workings of the components, to building instructions for a sample implementation of each subsystem on a robot called Squarebot. The examples are probably the most useful, as they illustrate both the construction and connecting that you will need in order to get your subsystems working together. The System Map (the large stand-alone poster sheet included with the Starter Kit) identifies the accessories that will allow you to easily expand your Vex Robotics Design System.

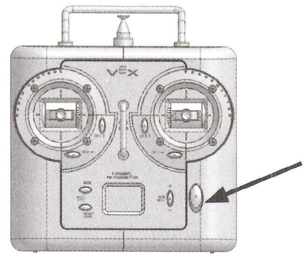
If you prefer to start with a basic robot and modify from there, then all you need to do is build all the subsystem examples. The six sample subsystems that are provided are all pieces of the Squarebot, and when attached according to the instructions in the chapters, you will have a simple, but working, robot that you can use as a starting point for your own designs.

Regarding ports and joystick controls, Appendix E has a full listing of control layouts that are available to you. The default controls are the simplest to deal with initially (because every channel controls the same-numbered motor port), but you may want to try switching to arcade-style controls to see if you like them better.

experienced users, continued

4 Test the robot

Once you have completed the robot (or even just a portion of it that you want to test), extend the antenna on the Transmitter and turn it on by flipping the power switch on the front.



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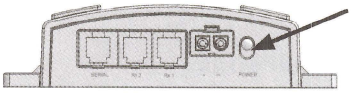

You should see green lights for the Power Status and Rx1, and the large light blinking occasionally.

You now have control over your robot. Remember that each axis of the stick or pair of buttons controls one of the output ports, so see if you can get your robot to move. You may want to try lifting it up if it looks stuck. Some motors may be trying to turn, but may be encountering unexpected resistance from other parts. Again, consult the Squarebot sample subsystems if you need help.

experienced users, continued

5 **Soccer Time**
Play the game! Challenge other teams for the best time, or see how many times in a row you can succeed by yourself.

6 **Improve your Design**
Nobody gets everything perfect the first time. Maybe your robot had trouble handling the ball in a turn, or maybe you think an entirely different strategy would work better. Go back and try it!

7 **Challenges**
When you're ready to move on to new, more challenging scenarios, turn to the Challenges chapter in the back of the Inventor's Guide. Pick one of the challenges there, and organize a tournament. Formulate a strategy to accomplish the goals in the game, and implement your robotic solutions. As you plan and build your robot, consult the Inventor's Guide for background information about the components you have available, and refer to the example subsystems for ideas.

8 **Venture Forth**
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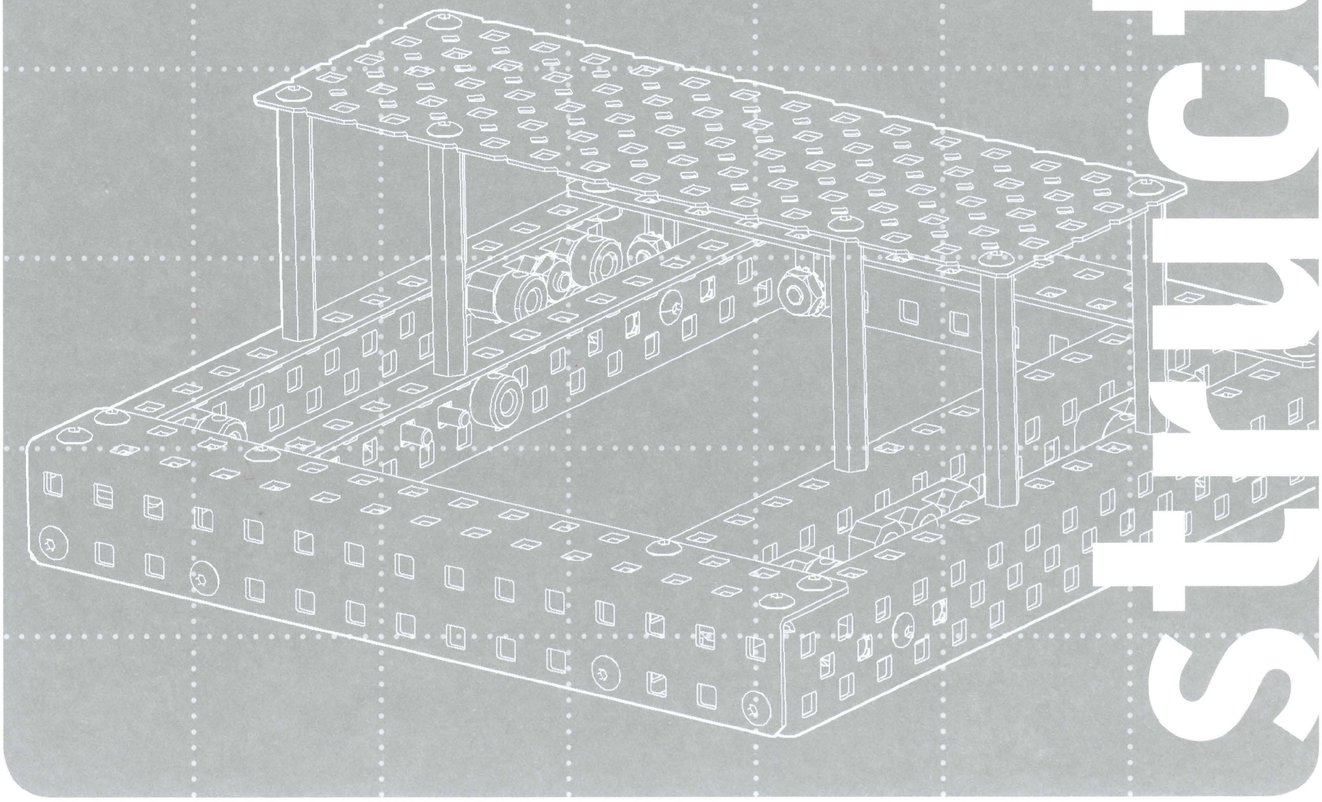
structure

The structural subsystem of the robot is responsible for physical support. It holds everything in place, and is, in effect, the durable “skeleton” of the robot to which all the other subsystems are attached.



structure

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squarebot chassis parts and assembly

The Structure and Motion subsystems are very tightly integrated to form the chassis of the Squarebot.

The chassis assembly instructions refer to components from both the Structure and Motion sections.

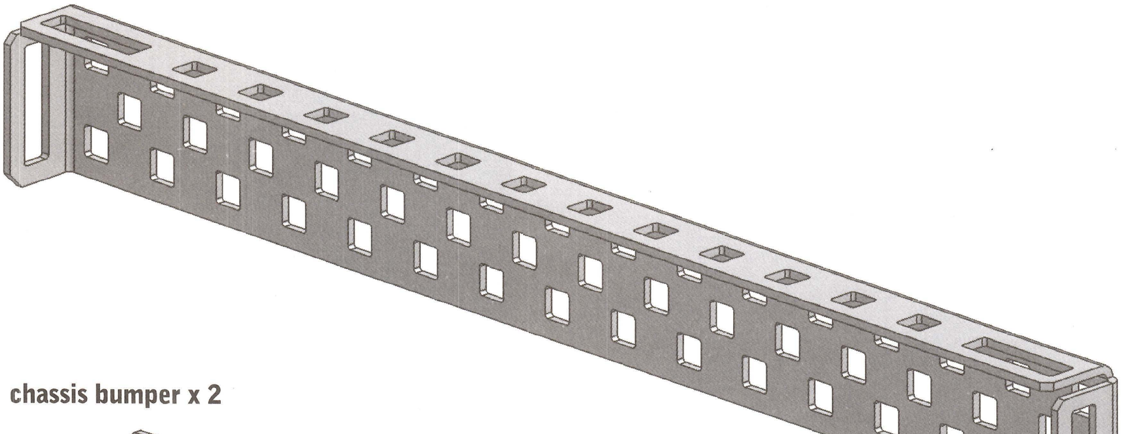
Follow the steps in this section to build the chassis.

① **Collect and identify the parts from the list of materials below:**

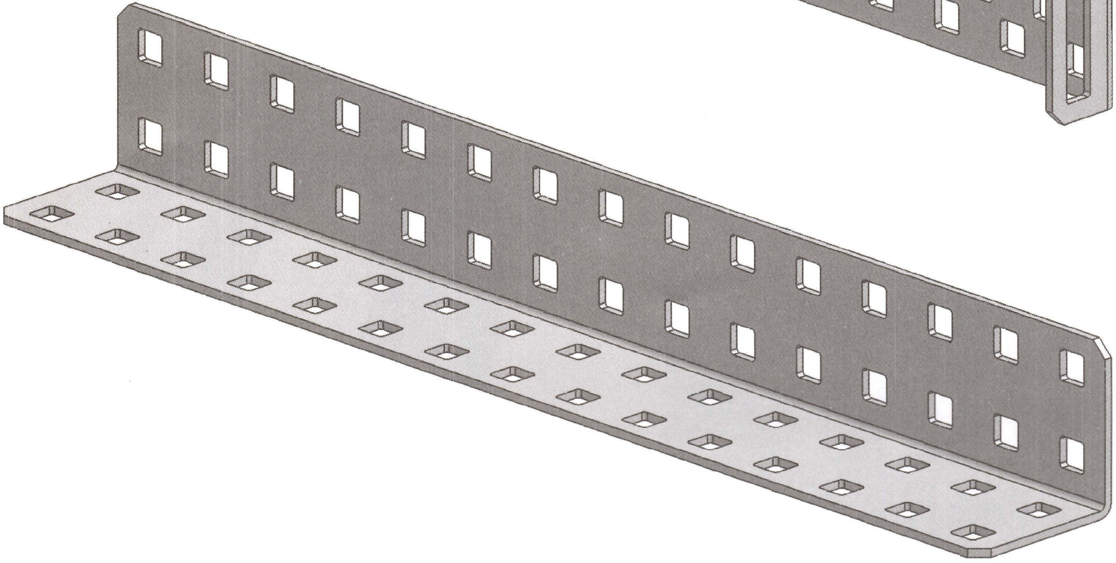
	materials	qty
structure subsystem	bearing flat	12
	panel	1
	chassis rail	4
	chassis bumper	2
	partially threaded beams, 2"	4
	keps nut	38
	8-32 hex screw, ¼"	26
	8-32 hex screw, ½"	20
motion subsystem	motor	2
	2.75" removable tire	4
	1.895" detachable hub	4
	36-tooth gear	4
	60-tooth gear	2
	collar w/ threaded set screw	10
	square bar, 2"	2
	square bar, 3"	4
	6-32 hex screw, ½"	4

squarebot chassis parts and assembly, continued

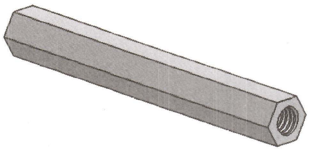
chassis rail x 4



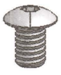
chassis bumper x 2



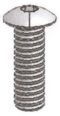
2" partially threaded beam x 4



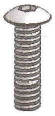
8-32 hex screw, ¼" x 26



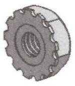
8-32 hex screw, ½" x 20



6-32 hex screw, ½" x 4

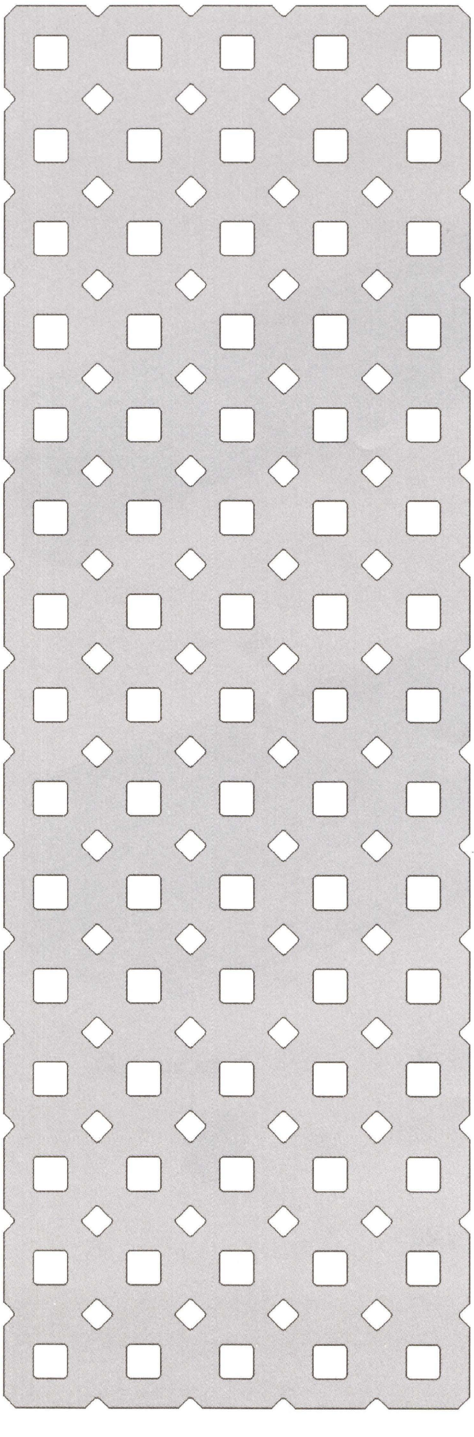


keps nut x 38

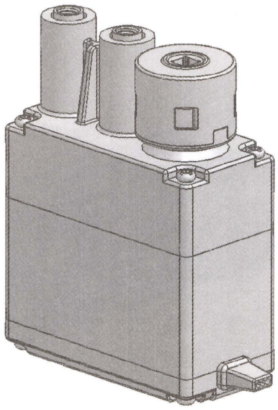


squarebot chassis parts and assembly, continued

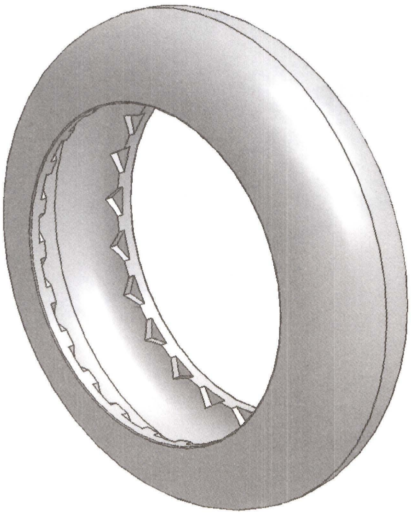
panel x 1



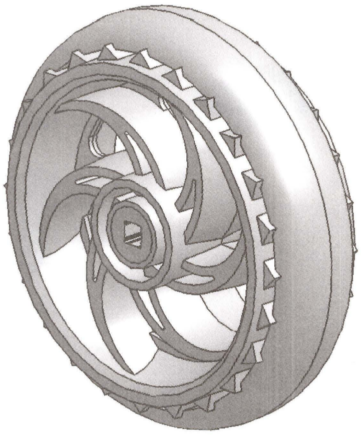
motor x 2



2.75" removable tire x 4

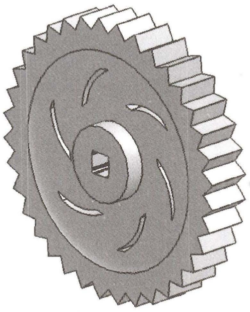


1.895" detachable hub x 4

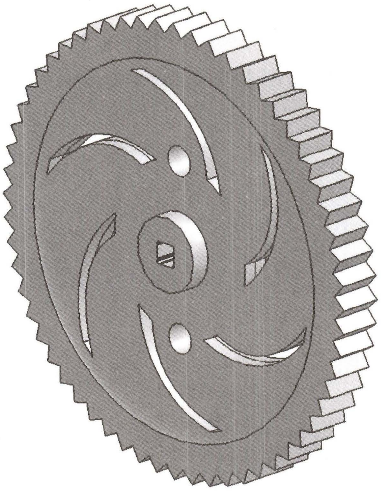


squarebot chassis parts and assembly, continued

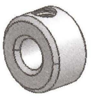
36 tooth gear x 4



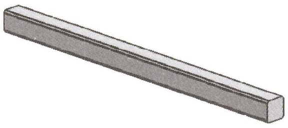
60 tooth gear x 2



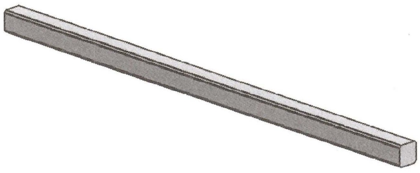
collar w/threaded set screw x 10



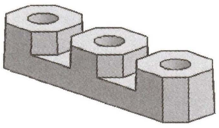
square bar, 2" x 2



square bar, 3" x 4



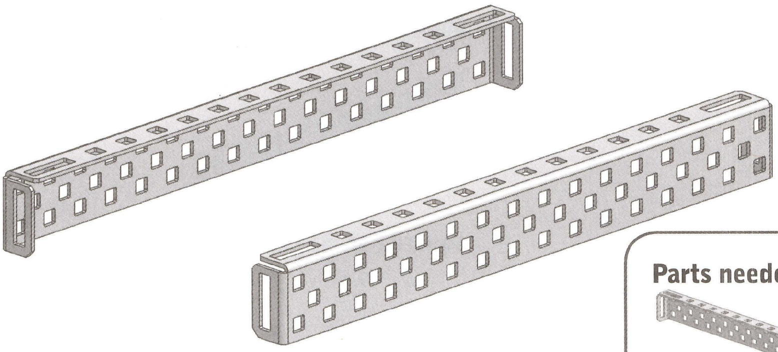
bearing flat x 12



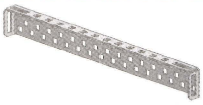
squarebot chassis parts and assembly, continued

2 Inner chassis rails

You will need two chassis rails, one for the right side and one for the left side. Orient them as shown, so that the narrow face is pointing up and the "open" sides are facing each other.

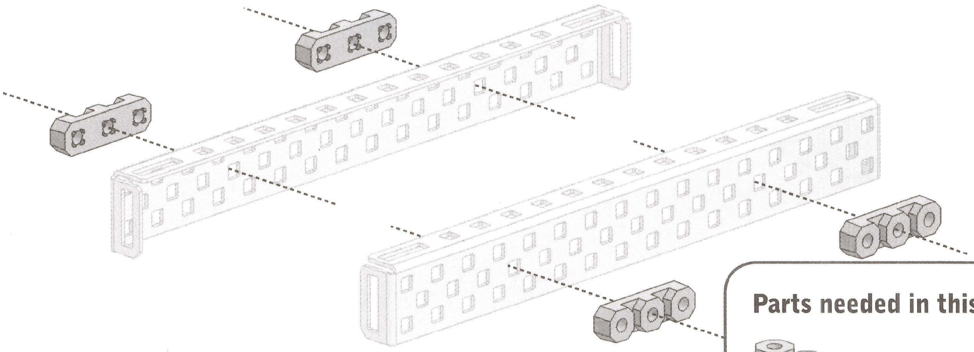


Parts needed in this step:

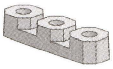


x 2

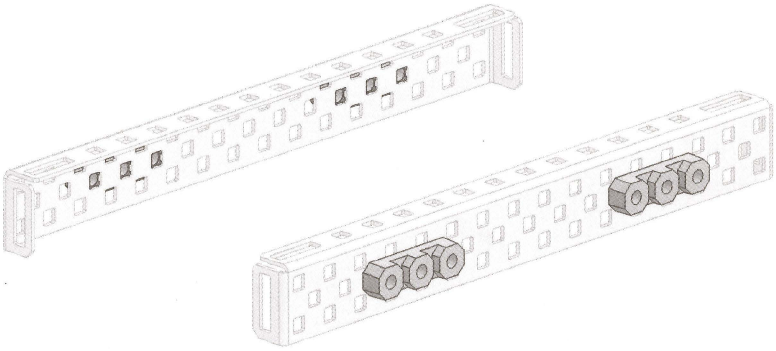
Add four bearing flats to the chassis rails (two per rail, on the outward-facing sides). Be sure to position the bearing flats such that the central hole of each bearing flat is aligned with the fourth hole from the respective end of the chassis rail, as shown.



Parts needed in this step:



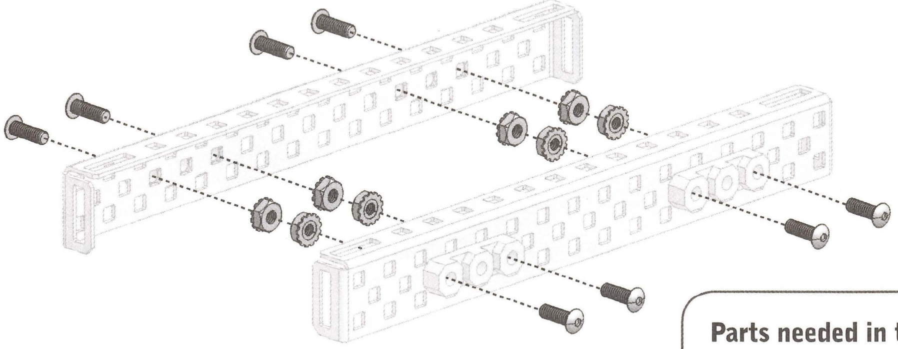
x 4



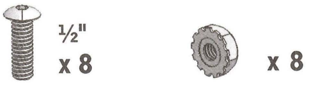
squarebot chassis parts and assembly, continued

2 Inner chassis rails, continued

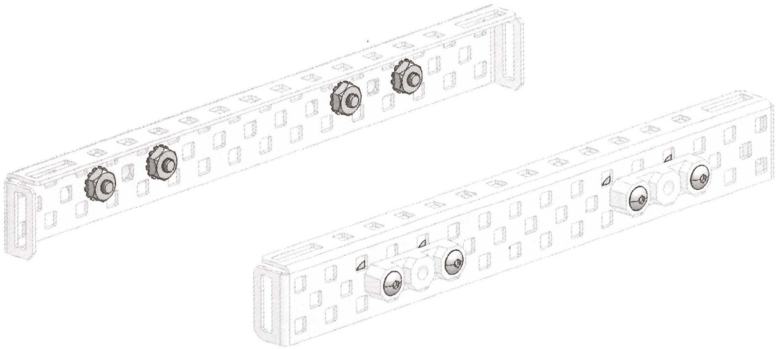
Secure the bearing flats to the chassis rails using two ½" 8-32 screws and two keps nuts per bearing flat, as shown.



Parts needed in this step:



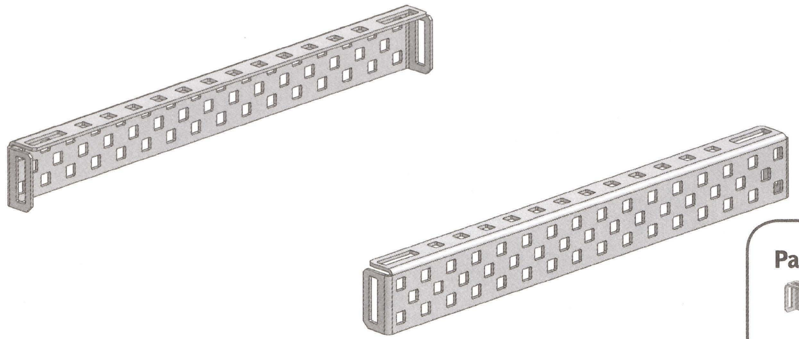
Your completed inner chassis rails should look like this when you're done:



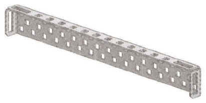
squarebot chassis parts and assembly, continued

2 Outer chassis rails

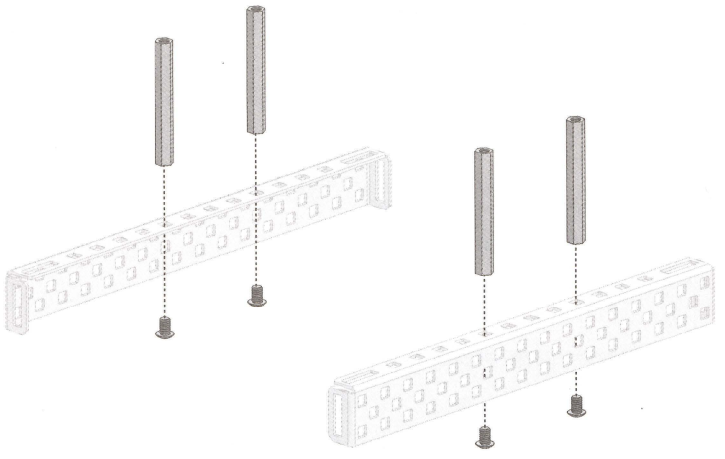
Position two more chassis rails as shown, just as you did for the inner chassis rails.

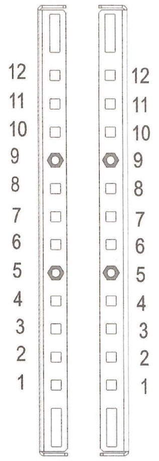


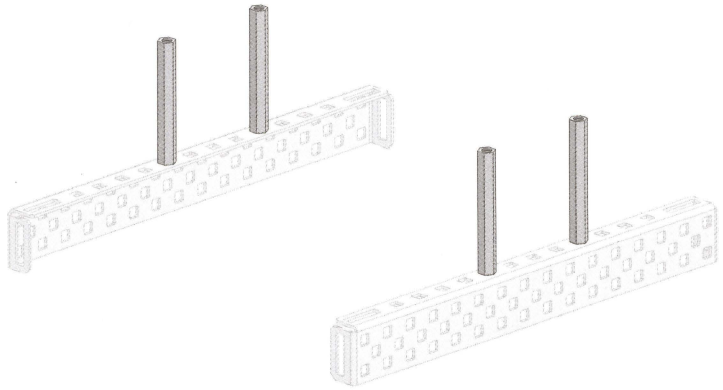
Parts needed in this step:



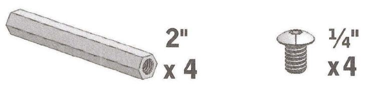
Connect two 2" partially threaded beams to each of the rails, using a ¼" 8-32 screw for each beam. Position the rear beam on the fourth square hole from the back end of the chassis rail, and the front beam on the fifth square hole from the front end of the chassis rail.







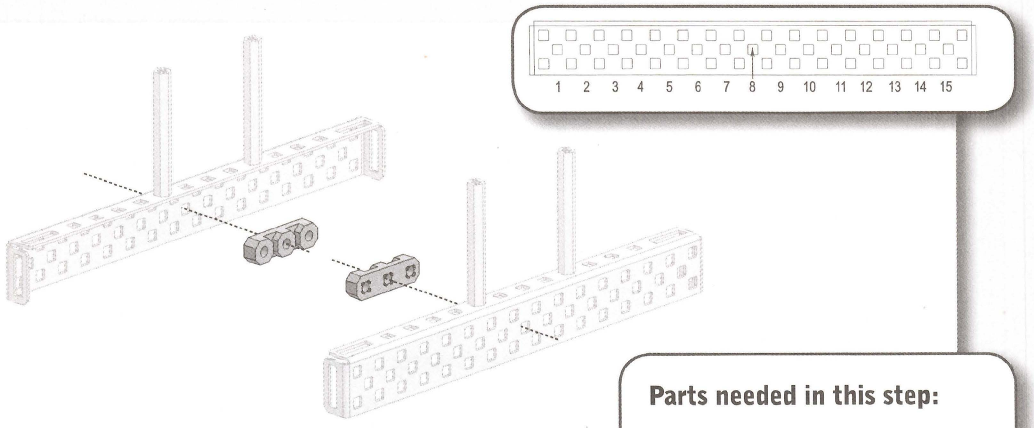
Parts needed in this step:



squarebot chassis parts and assembly, continued

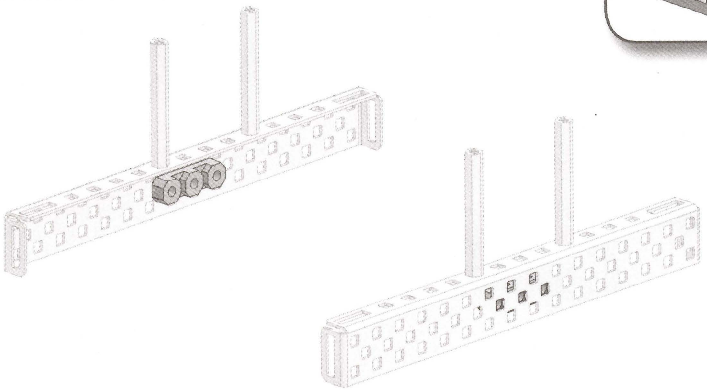
2 Outer chassis rails, continued

Add bearing flats to the inner faces of the two chassis rails. The center hole of the bearing flat should be aligned with the eighth hole from the front end of the chassis rail, in the middle row of holes.



Parts needed in this step:

x 2

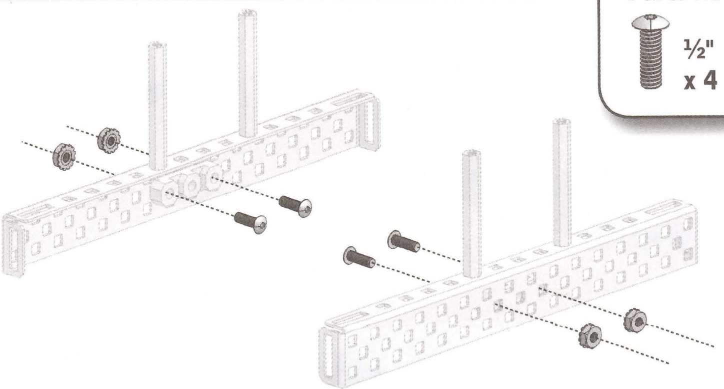


Secure each bearing flat with two ½" 8-32 screws and two keps nuts.

Parts needed in this step:

½"
x 4

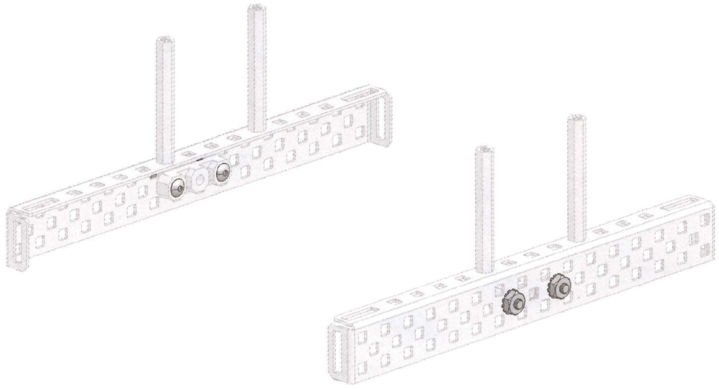
x 4



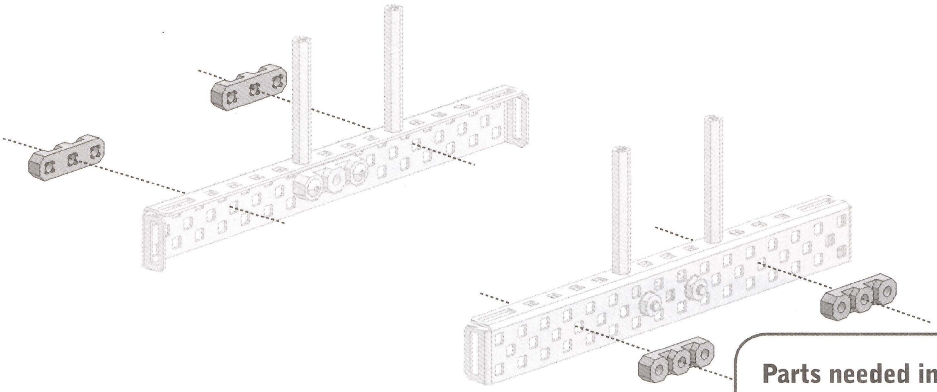
squarebot chassis parts and assembly, continued

2 Outer chassis rails, continued

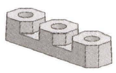
Your outer chassis rails should now look like this:



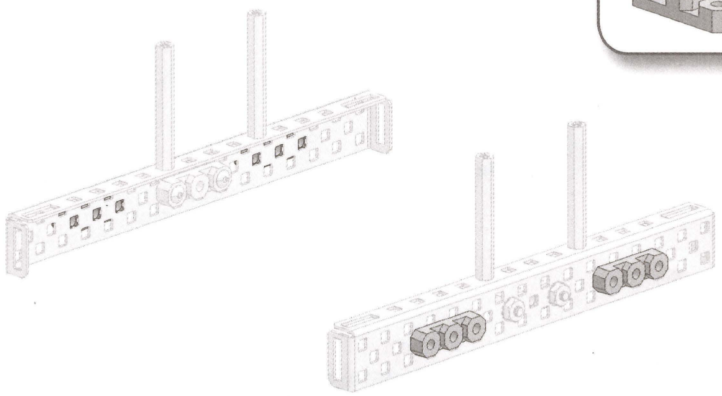
Now add two bearing flats to the outer surface of each chassis rail, so the center hole of each bearing flat is over the fourth hole from the respective end of the chassis rail, as shown. These are the same positions as the bearing flats you put on the inner chassis rails earlier.



Parts needed in this step:



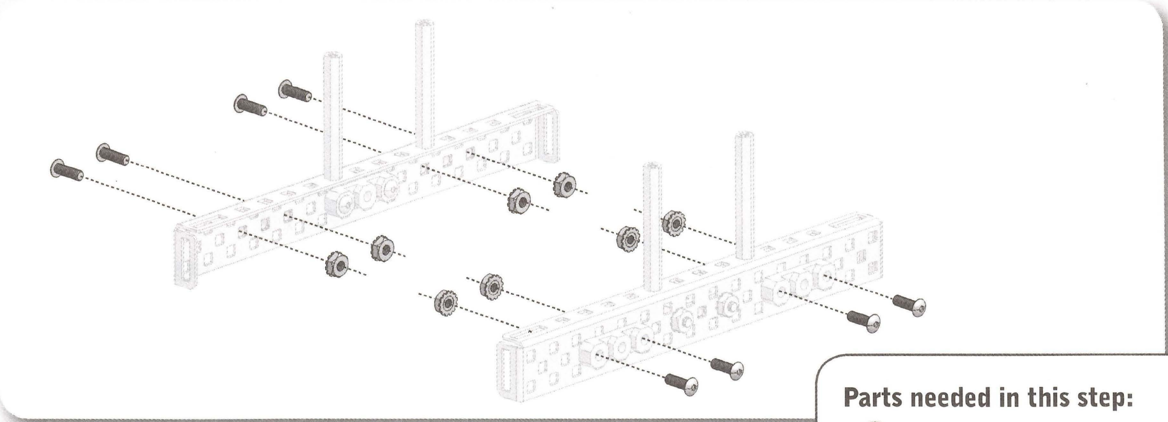
x 4



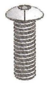
squarebot chassis parts and assembly, continued

2 Outer chassis rails, continued

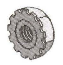
Again, secure the bearing flats to the chassis rails using two two ½" 8-32 screws and two keps nuts per bearing flat.



Parts needed in this step:

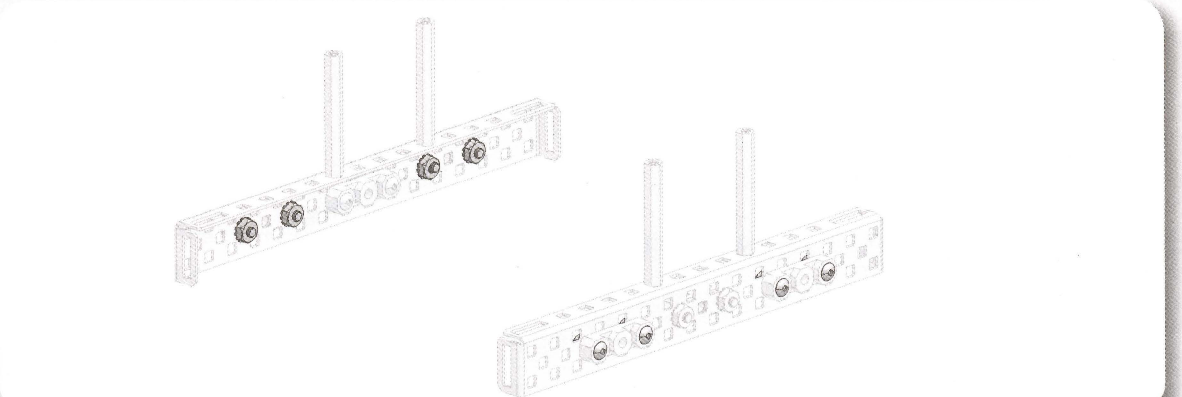


½"
x 8



x 8

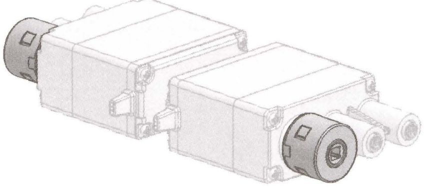
Your outer chassis rails should now look like this:



squarebot chassis parts and assembly, continued

3 Motor Subassembly

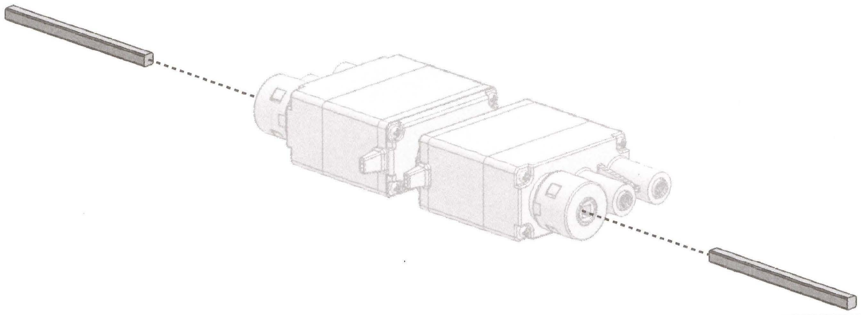
Before starting on the motor subassembly, make sure that the clutch is installed in the motor, as shown.



Parts needed in this step:

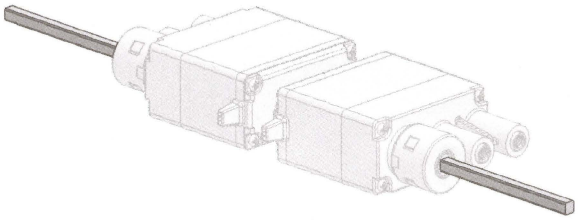
x 2

Insert a 2" square beam into each clutch, making sure that they seat firmly. The square bar will act as the motor's drive shaft.



Parts needed in this step:

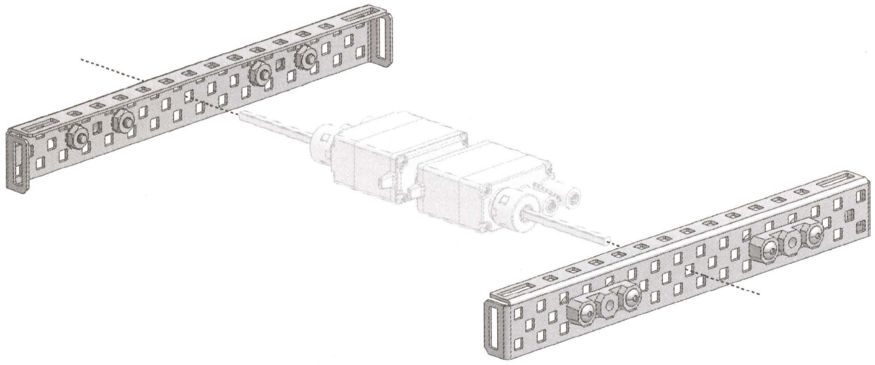
2"
x 2

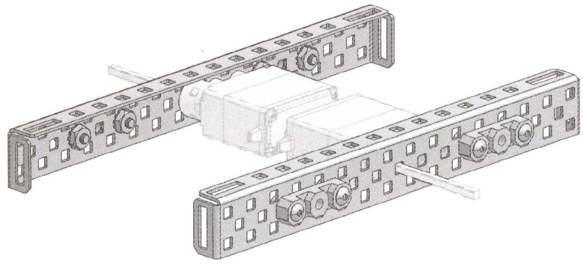


squarebot chassis parts and assembly, continued

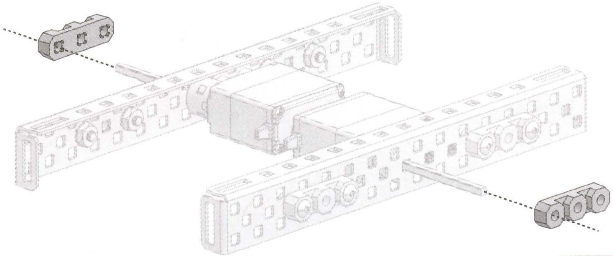
3 Motor Subassembly, continued

Slide the pre-assembled inner chassis rails onto the square bar motor shafts, so that the shafts go through the middle hole in the middle row of each rail.

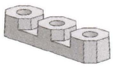




Install one bearing flat on the outward-facing side of each chassis rail, with the front hole of the bearing flat sliding onto the motor shaft as shown.



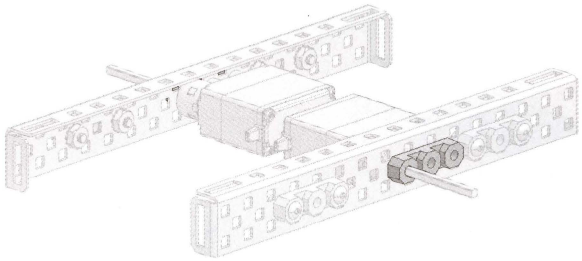
Parts needed in this step:


x 2

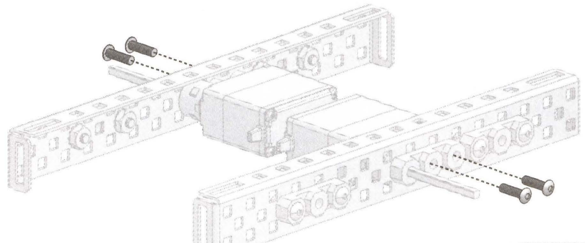
squarebot chassis parts and assembly, continued

3 Motor Subassembly, continued

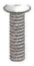
Your assembly should now look like this:



Secure the bearing flat to the inner chassis rail and motor using two ½" 6-32 screws per motor. Note that these are the thinner screws, not the usual 8-32 ones.

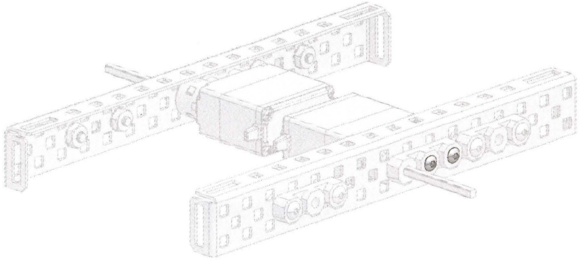


Parts needed in this step:



½"
x 4

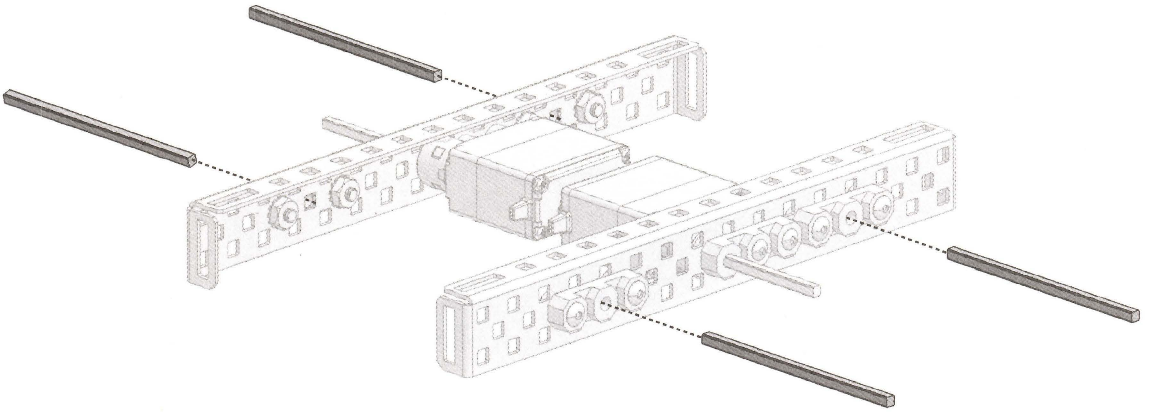
Your assembly should now look like this:



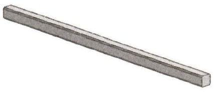
squarebot chassis parts and assembly, continued

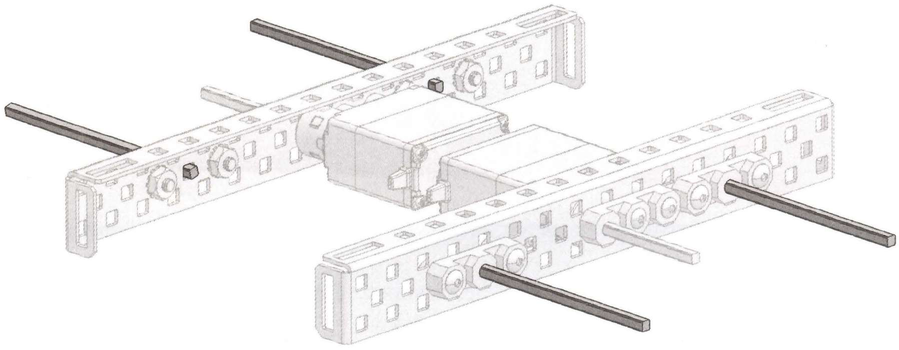
3 Chassis Subassembly

Insert a 3" square bar through the center hole of each unoccupied bearing flat, as shown. Don't push them all the way through. Push the end of the bar about 1/8" through the rail.



Parts needed in this step:

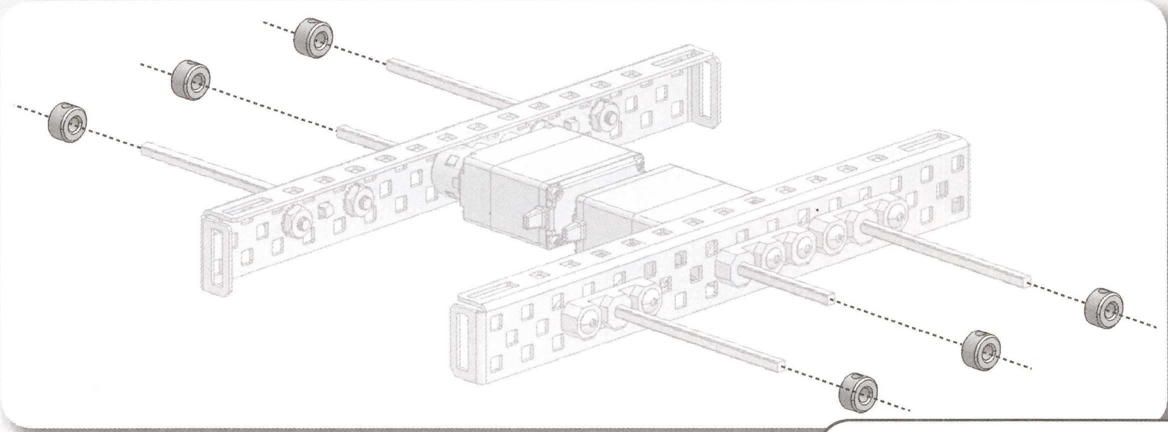




squarebot chassis parts and assembly, continued

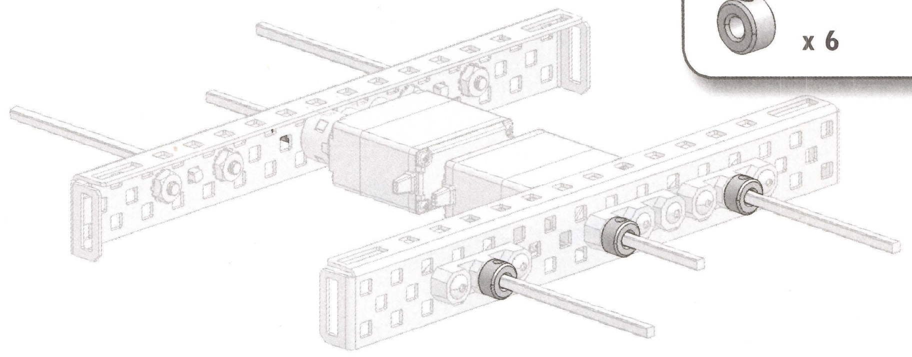
4 Chassis Subassembly, continued

Slide metal collars (with threaded screws) onto each of the 2" and 3" square bars, mounting them flush with the surface of the bearing flat against which they will sit. Be sure the square bars don't get pushed too far in while you put the collars on, or you will not have enough bar sticking out to mount the wheels later.

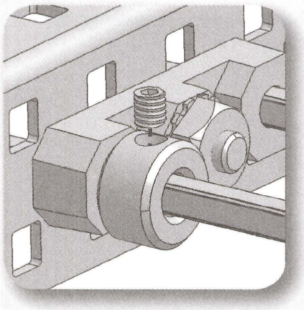


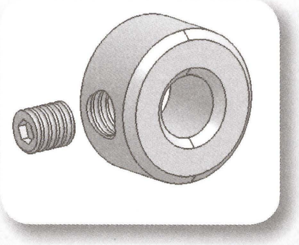
Parts needed in this step:

x 6



Once the collars and bars are in position, tighten the threaded screws with the smaller 5/64" hex L wrench to keep the collars from sliding out of place.

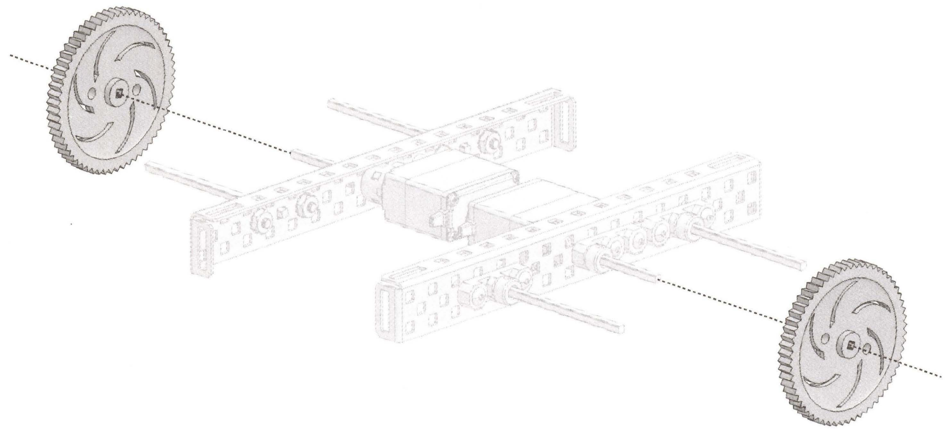




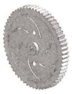
squarebot chassis parts and assembly, continued

4 Chassis Subassembly, continued

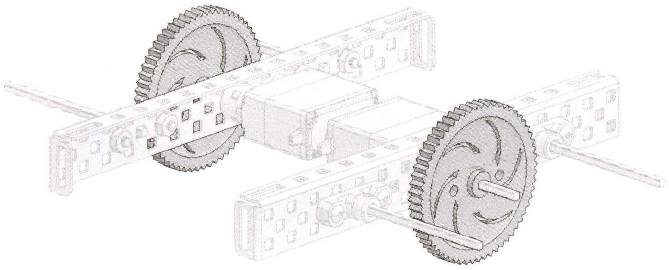
Slide a 60-tooth gear onto the drive axle of each motor, pushing it flush against the collar that you added in the previous step.



Parts needed in this step:



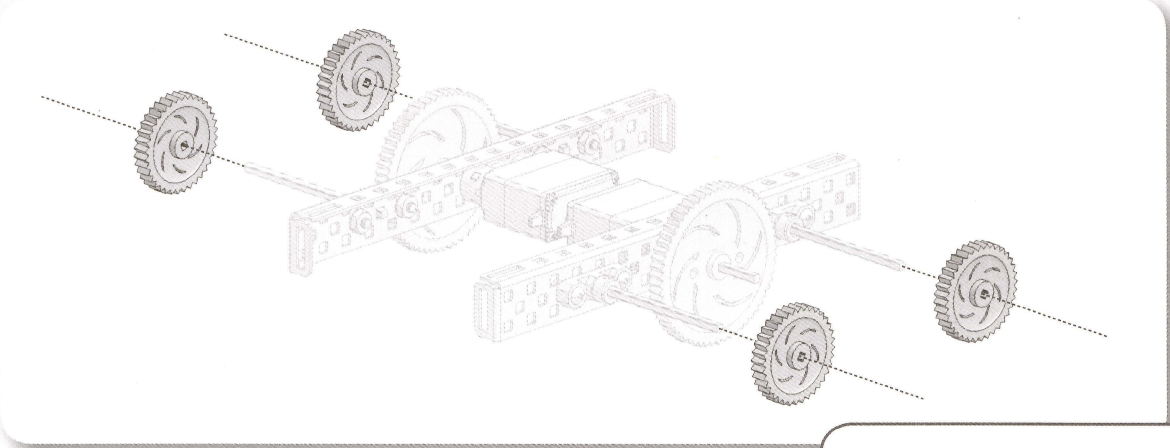
60-tooth
x 2



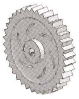
squarebot chassis parts and assembly, continued

4 Chassis Subassembly, continued

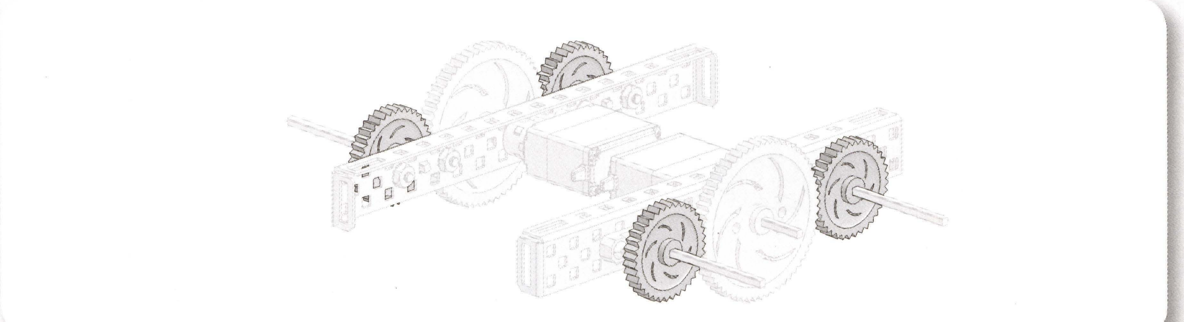
Slide a 36-tooth gear onto each of the remaining square bars, pushing them flush against the collars.



Parts needed in this step:



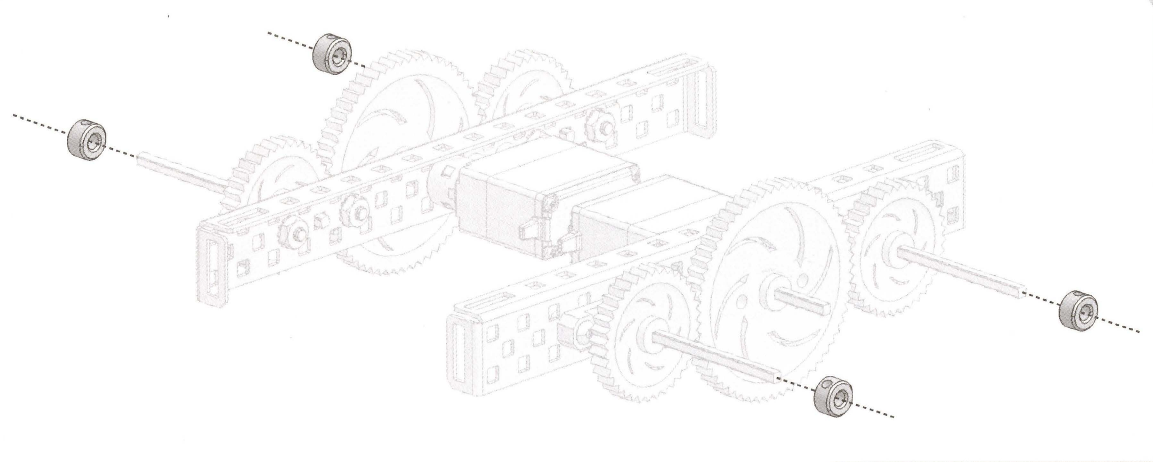
36-tooth
x 4

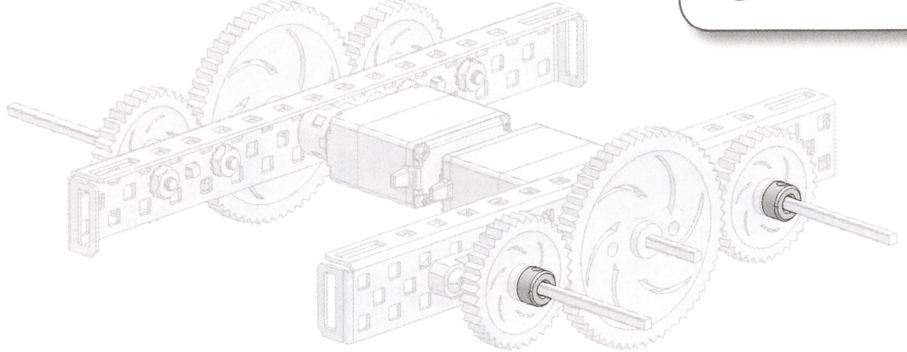


squarebot chassis parts and assembly, continued

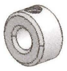
4 Chassis Subassembly, continued

Add another collar to the end of each 3" square bar, again pushing them flush against the face of the gear before tightening the screws.



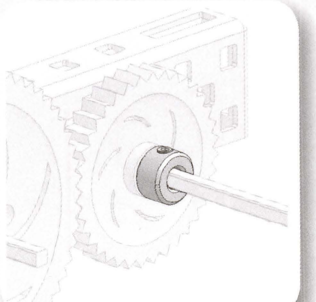


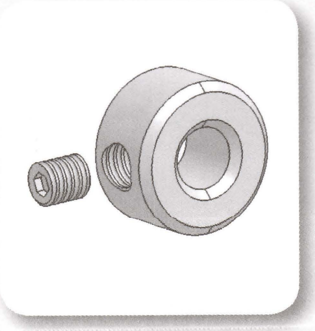
Parts needed in this step:



x 4

Tighten the threaded screws with a 35/64" hex L wrench.

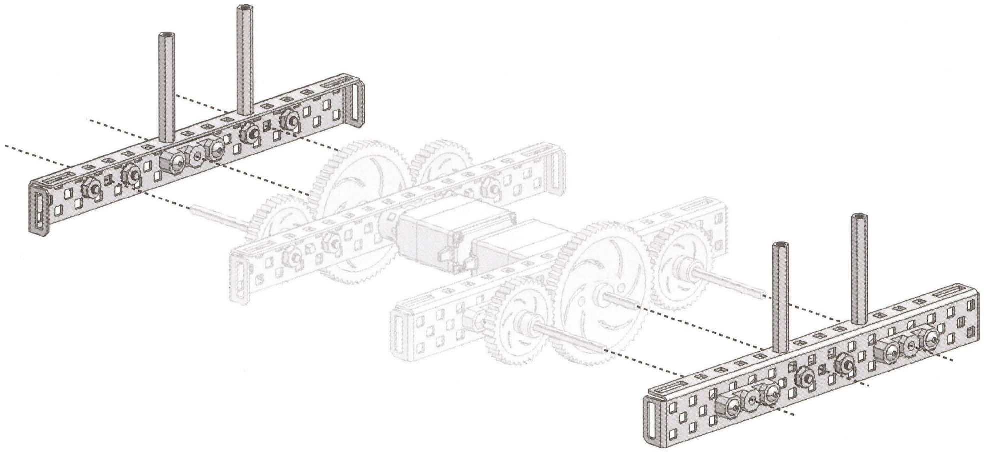


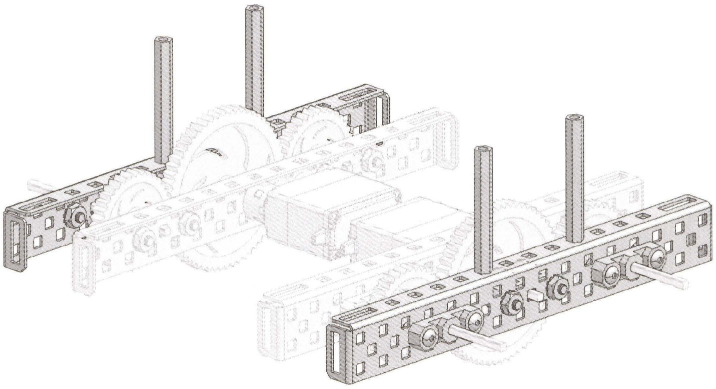


squarebot chassis parts and assembly, continued

4 Chassis Subassembly, continued

Install the pre-assembled outer chassis rails onto the current assembly. All three of the square bars sticking out of the inner rail should go neatly through bearing flats on the outer rail.



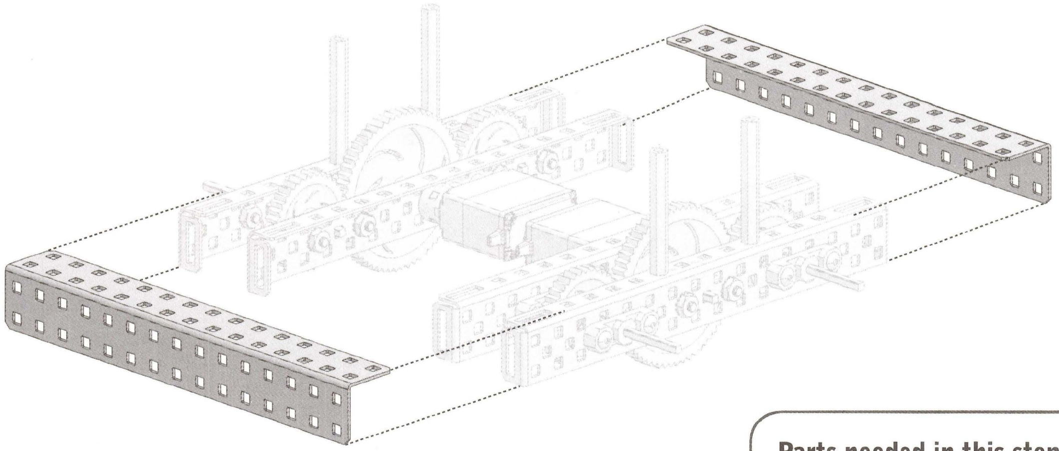


Note: If you find that your gears are sliding on the axles, you can insert the 0.182" and 0.318" plastic spacers included in the kit to block them into place.

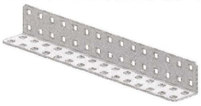
squarebot chassis parts and assembly, continued

4 Chassis Subassembly, continued

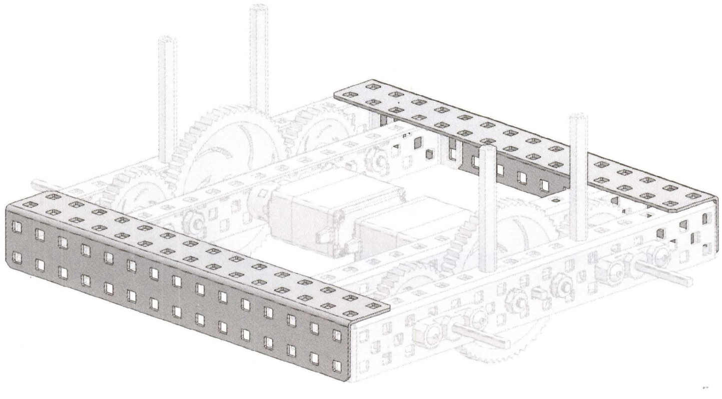
Place chassis bumpers on the front and rear of the chassis rails, as shown.



Parts needed in this step:



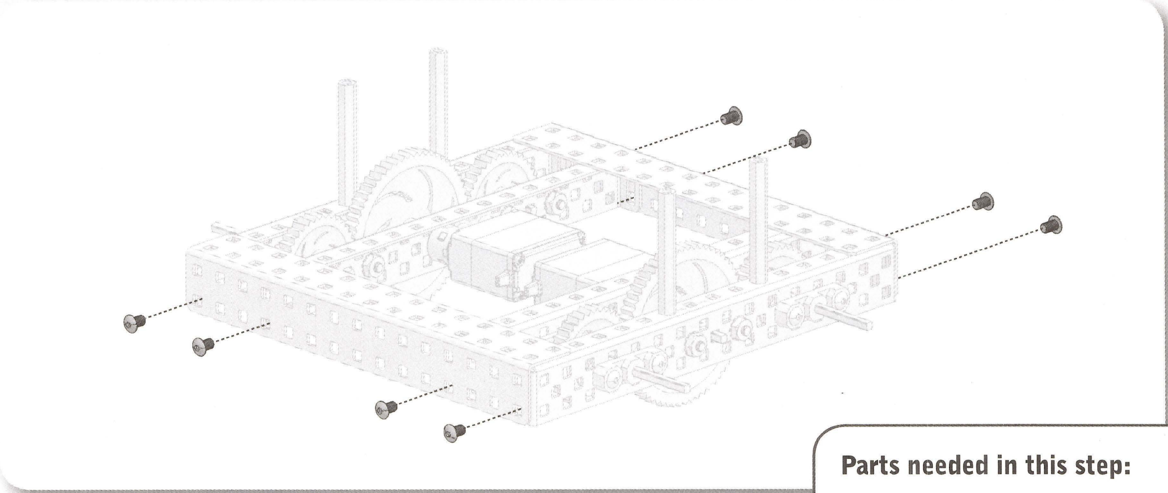
x 2

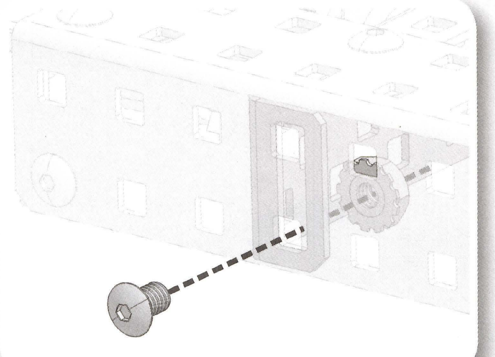


squarebot chassis parts and assembly, continued

4 Chassis Subassembly, continued

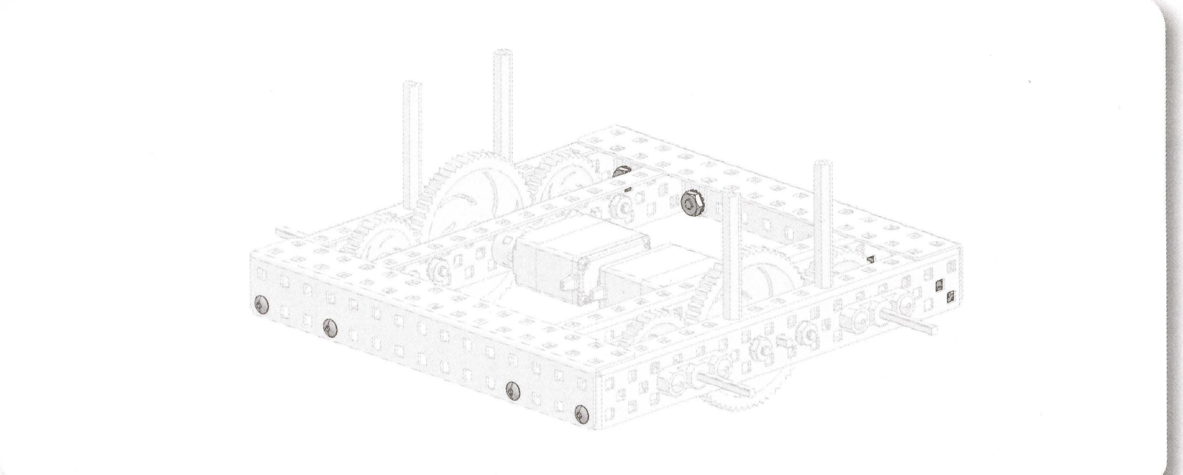
Secure the vertical faces of the chassis bumpers to the end of the chassis rails using four ¼" 8-32 screws and keps nuts in the front, and four in the back.





Parts needed in this step:

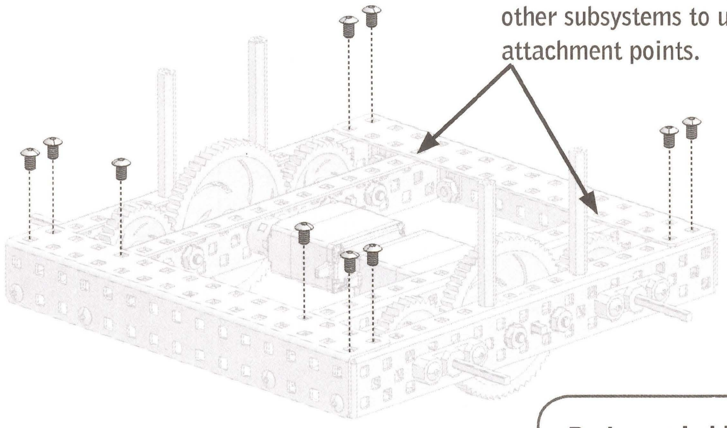
¼" x 8	x 8



squarebot chassis parts and assembly, continued

4 Chassis Subassembly, continued

Secure the horizontal faces of the chassis bumpers to the top of the chassis rails using ¼" 8-32 screws and keps nuts, six in the front and four in the back.

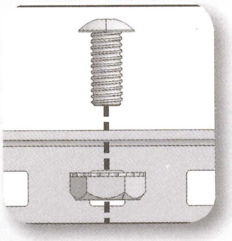


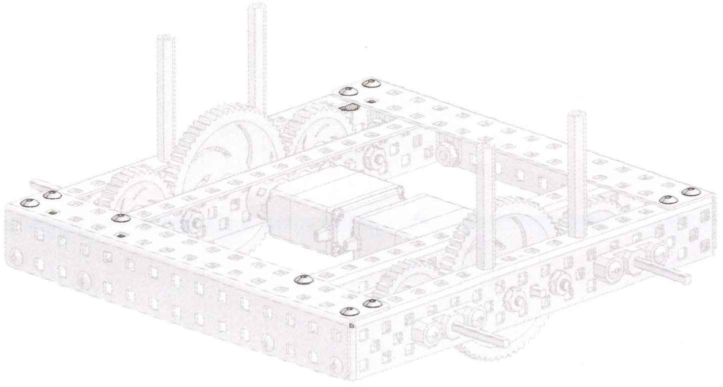
These holes remain open to allow other subsystems to use them as attachment points.

Parts needed in this step:

¼" x 10

x 10

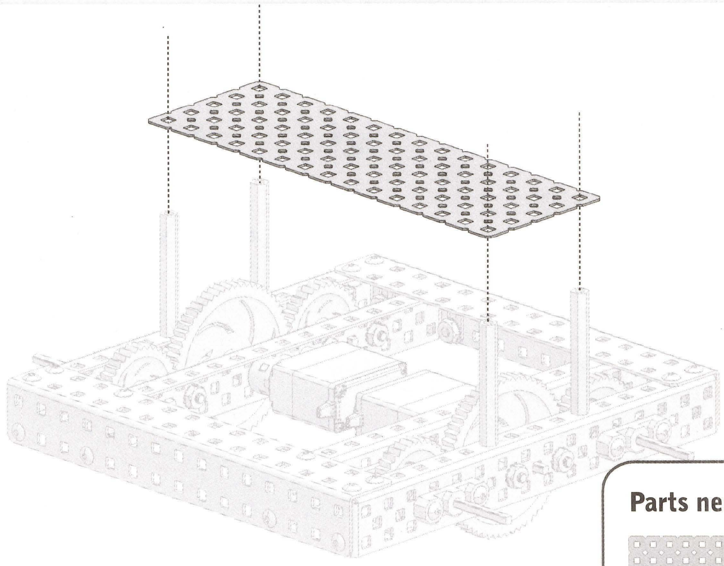




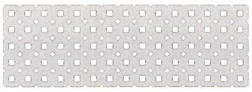
squarebot chassis parts and assembly, continued

4 Deck Subassembly

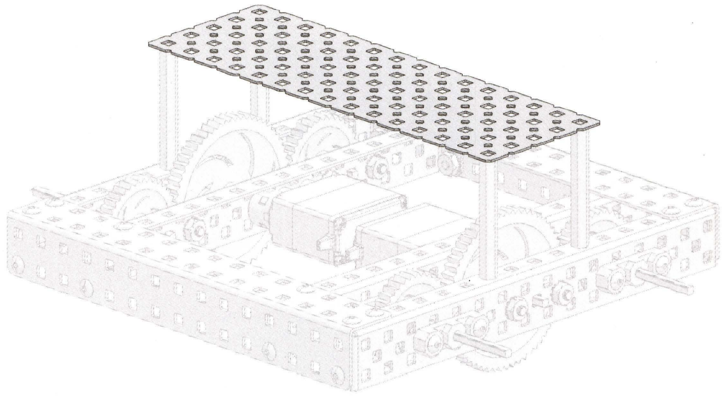
Place the large flat panel on the 2" partially threaded beams, aligning each corner of the panel with one of the threaded beams.



Parts needed in this step:



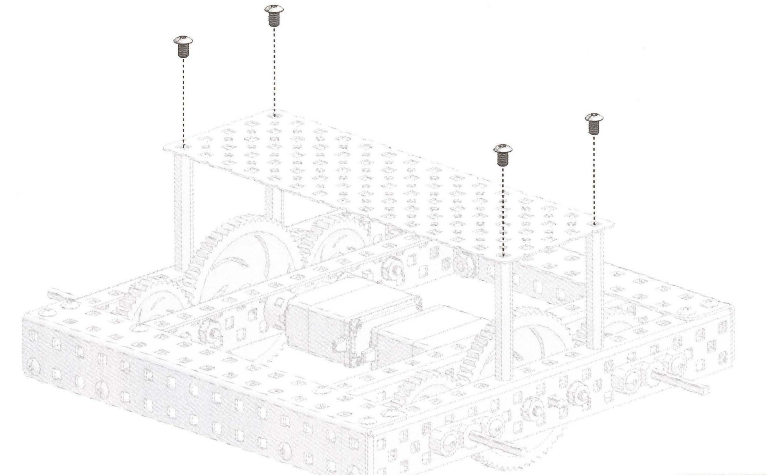
x 1



squarebot chassis parts and assembly, continued

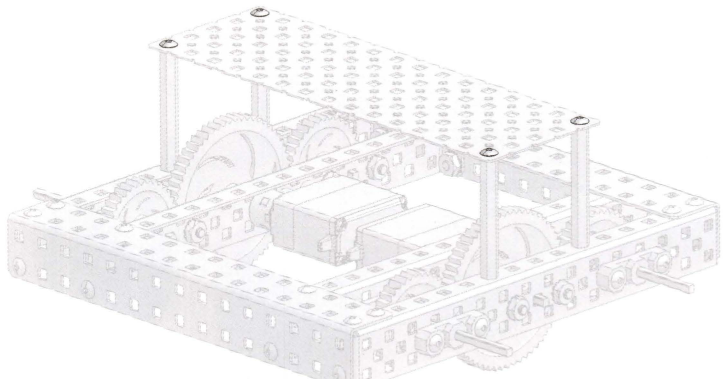
4 Deck Subassembly

Secure the panel to the threaded beams with four ¼" 8-32 screws, as shown.



Parts needed in this step:

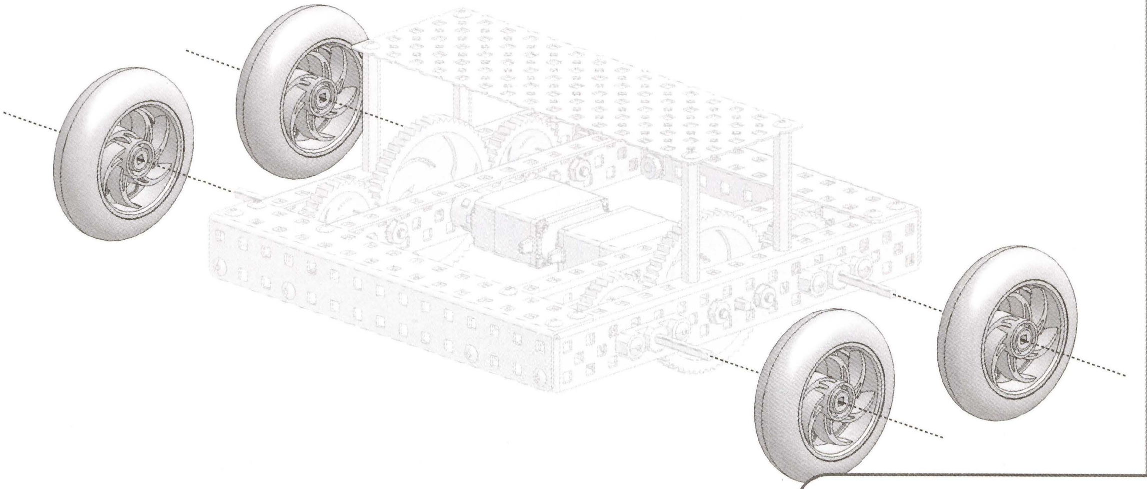
¼"
x 4



squarebot chassis parts and assembly, continued

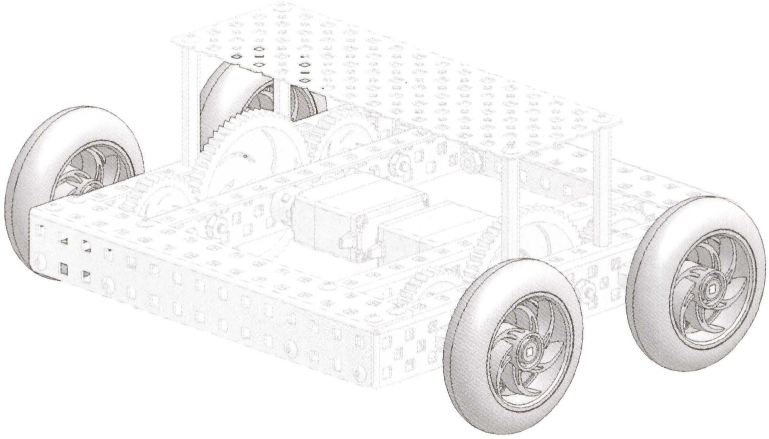
4 Deck Subassembly

Install the small green tires (2.75" Removable Tire and 1.895" Hub) on the 3" square beams, as shown.



Parts needed in this step:

x 2

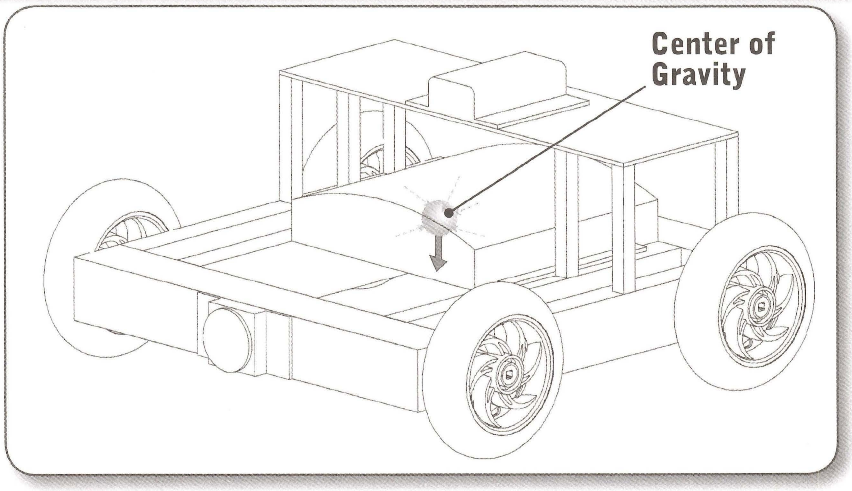


Your Squarebot chassis is complete!

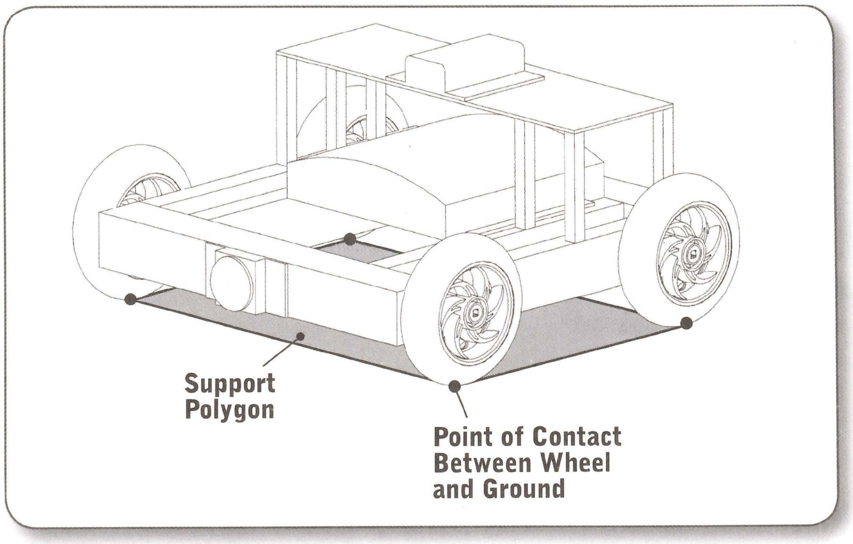
concepts to understand

Stability: Center of Gravity Considerations

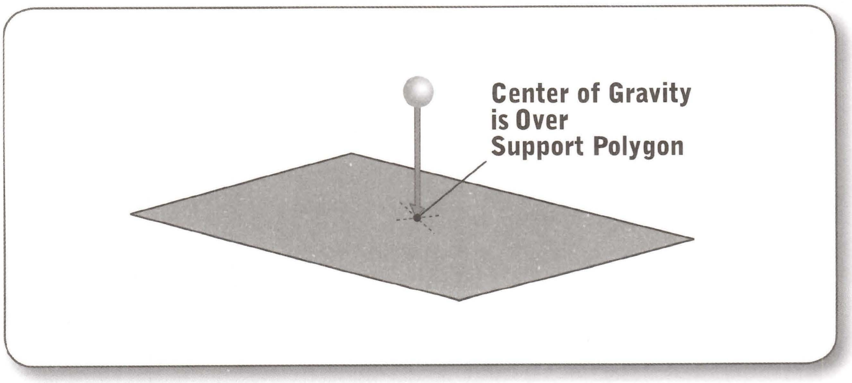
Center of Gravity
You can think of the robot's center of gravity as the "average position" of all the weight on the robot. Because it is an average of both weight and position, heavier objects count more than lighter ones in determining where the center of gravity is, and pieces that are farther out count more than pieces that are near the middle.


Center of Gravity

Support Polygon
The support polygon is the imaginary polygon formed by connecting the points where your robot touches the ground (usually the wheels). It varies by design, but there is always one support polygon in any stable configuration.


Support Polygon
Point of Contact Between Wheel and Ground

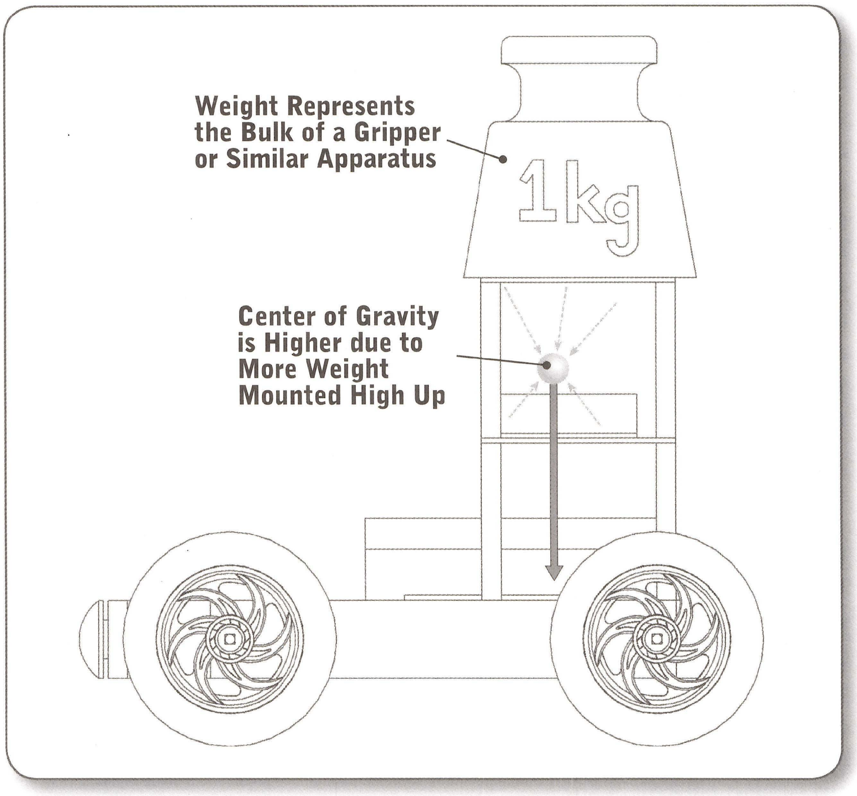
Stability
The rule for making a robot stable is very simple: the robot will be most stable when the center of gravity is centered over the polygon. Your robot will encounter much more complex situations than just standing still, however, and you need to take these into account when making your design.


Center of Gravity is Over Support Polygon

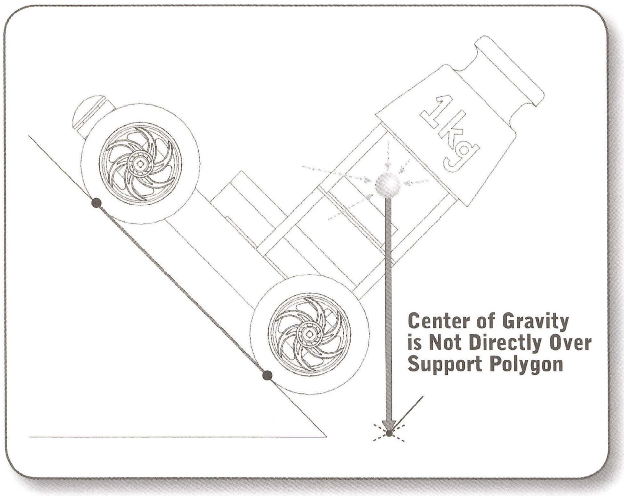
concepts to understand, continued

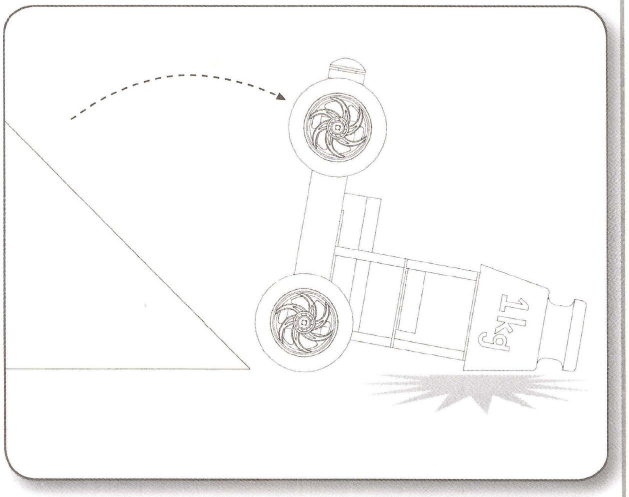
Stability: Center of Gravity Considerations, continued

EXAMPLE 1: Towerbot
This robot was built very tall so that it would be able to reach a hanging goal for a challenge. However, along the way, it had to first climb a ramp.


Weight Represents the Bulk of a Gripper or Similar Apparatus
1kg
Center of Gravity is Higher due to More Weight Mounted High Up

Notice that the robot's center of gravity is no longer over the support polygon. This robot would fall over as soon as it started up the ramp.


1kg
Center of Gravity is Not Directly Over Support Polygon

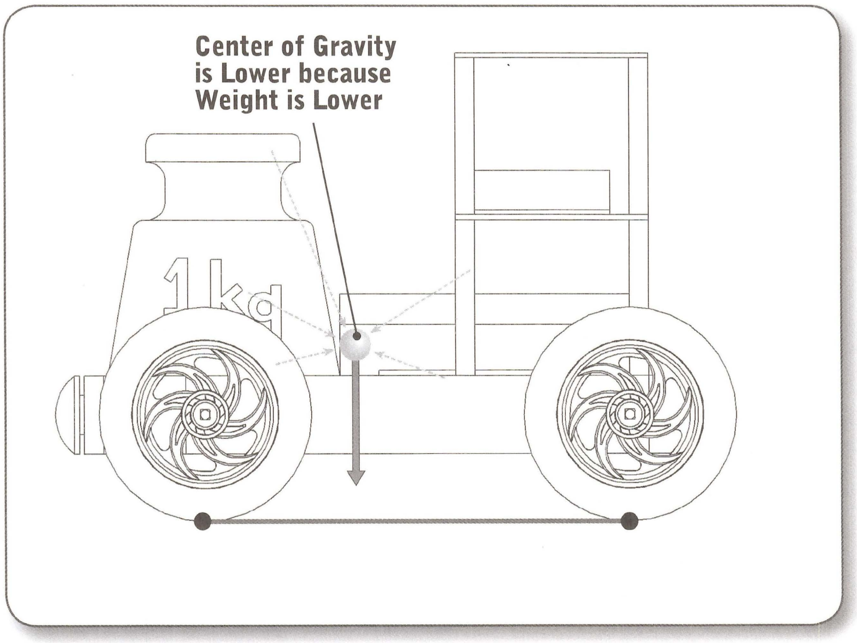


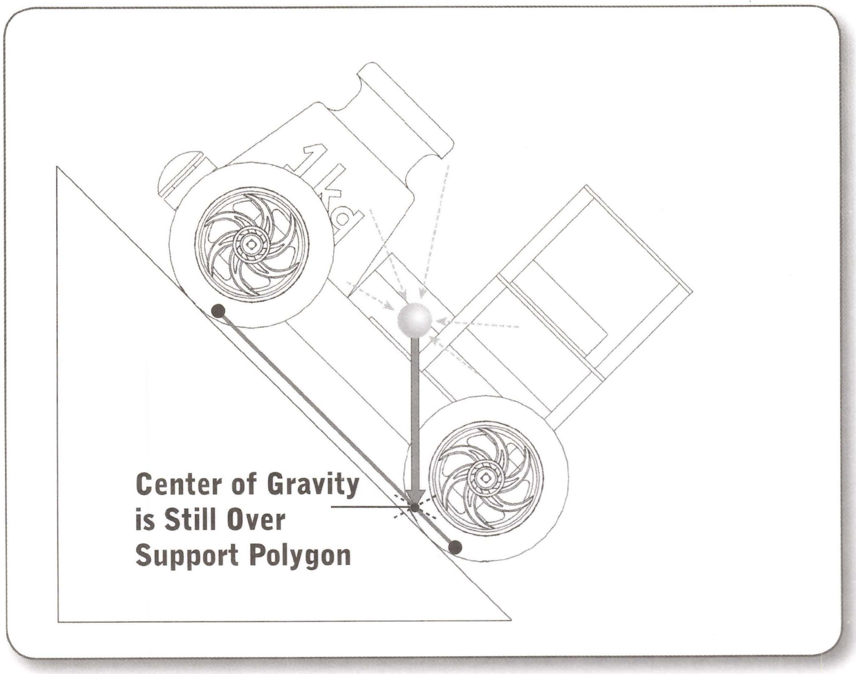
concepts to understand, continued

Stability: Center of Gravity Considerations, continued

EXAMPLE 1: Towerbot, continued

To fix this problem, you must lower the robot's center of gravity so that it does not move as far when the robot is on an incline. In general, it is always advantageous to have your robot's center of gravity as close to the ground as possible!

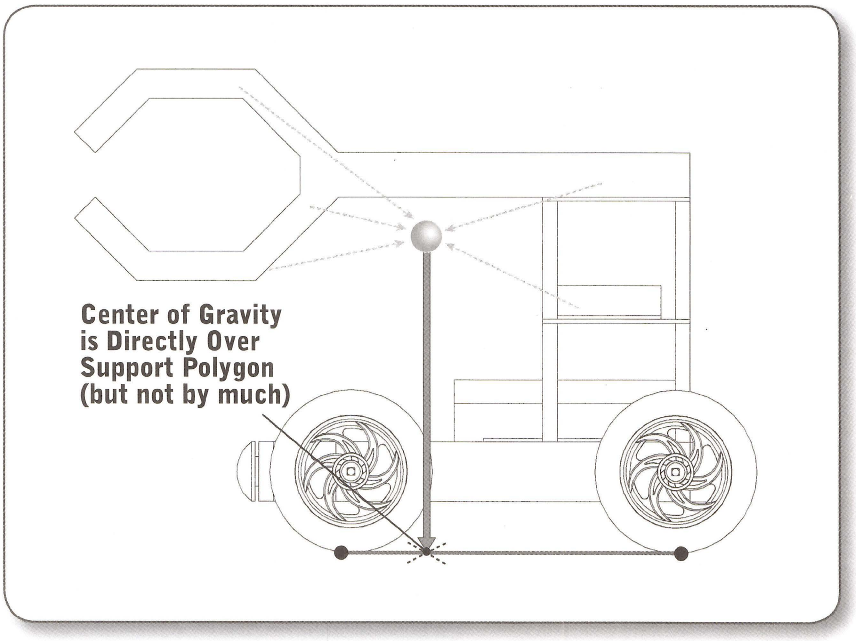

Center of Gravity is Lower because Weight is Lower
1kg


1kg
Center of Gravity is Still Over Support Polygon

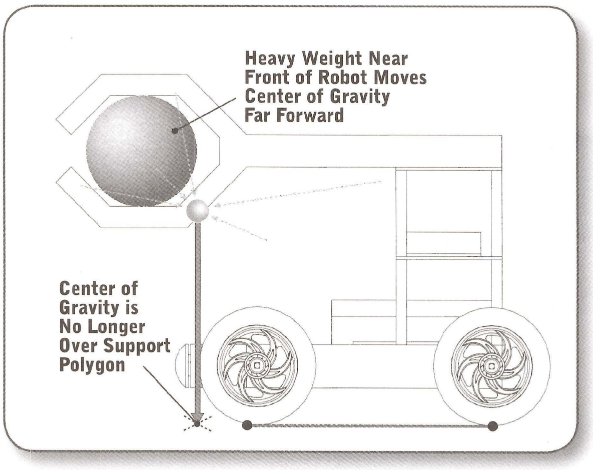
concepts to understand, continued

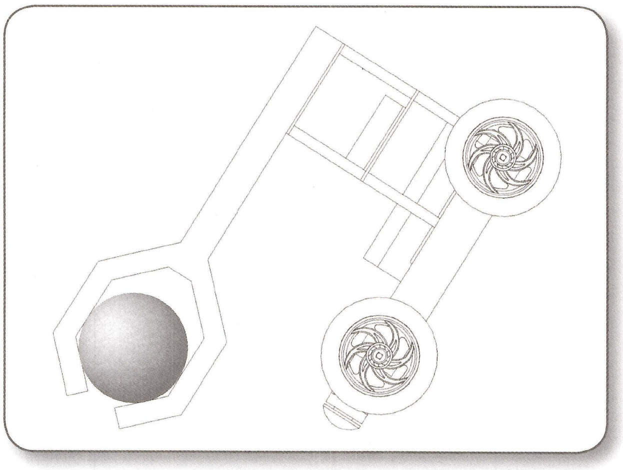
Stability: Center of Gravity Considerations, continued

EXAMPLE 2: Grabberbot
This robot is designed to pick up a heavy object using the gripper claw on the front, and transport the object to another location.


Center of Gravity
is Directly Over
Support Polygon
(but not by much)

When the robot picks up the object, it effectively adds it to the robot's structure. The combined robot-ball structure now has the new center of gravity (shown below), which is outside the support polygon. The robot tips over as a consequence.


Heavy Weight Near
Front of Robot Moves
Center of Gravity
Far Forward
Center of
Gravity is
No Longer
Over Support
Polygon

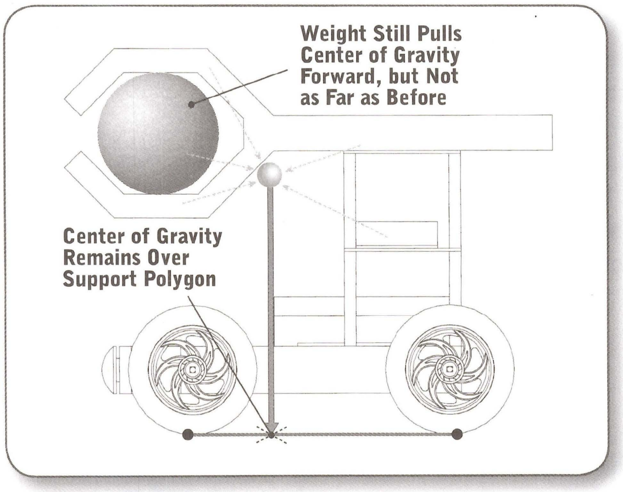


concepts to understand, continued

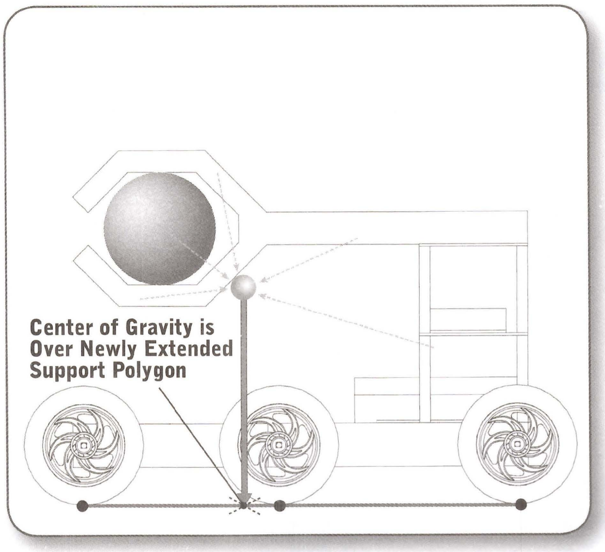
Stability: Center of Gravity Considerations, continued

EXAMPLE 2: Grabberbot, continued
There are many solutions to this problem. Depending on the specifics of the challenge, some or all of these modifications could work:

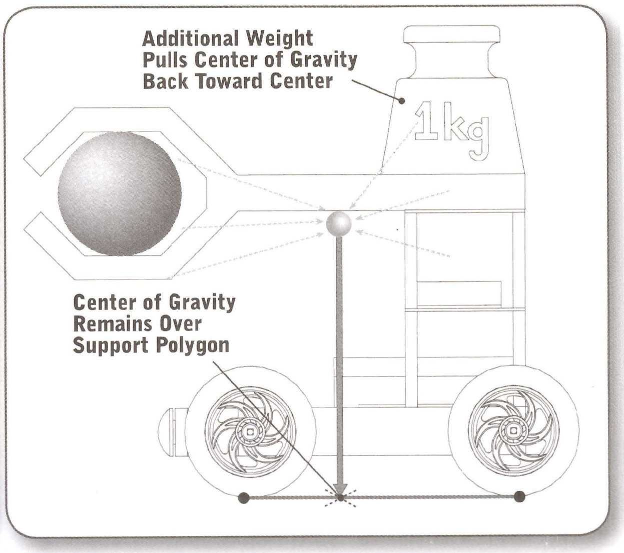
Moving the center of gravity back by moving the gripper farther back on the robot


Weight Still Pulls Center of Gravity Forward, but Not as Far as Before
Center of Gravity Remains Over Support Polygon

Extending the support polygon by adding more wheels farther out


Center of Gravity is Over Newly Extended Support Polygon

Moving the center of gravity back by adding counterweights on the back of the robot

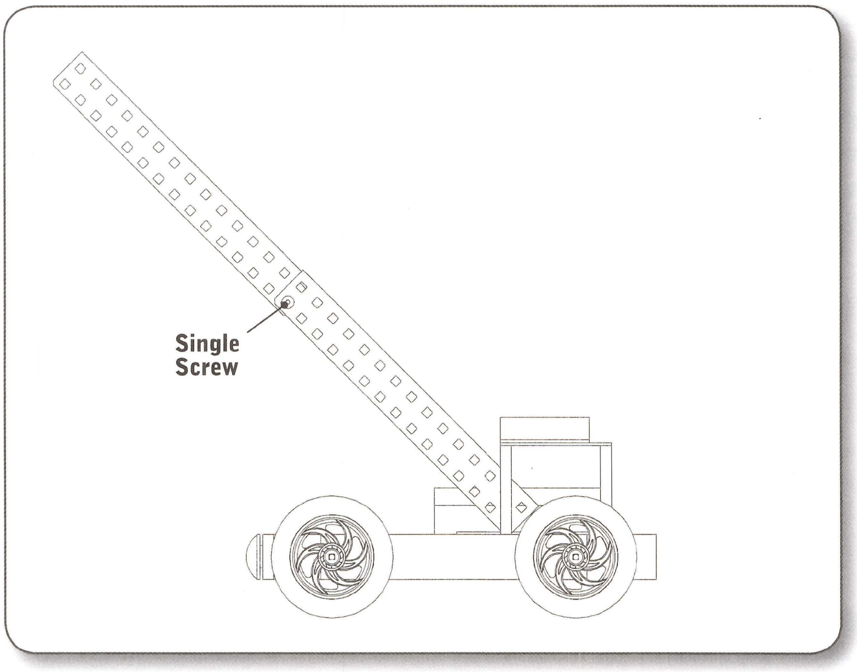

Additional Weight Pulls Center of Gravity Back Toward Center
1kg
Center of Gravity Remains Over Support Polygon

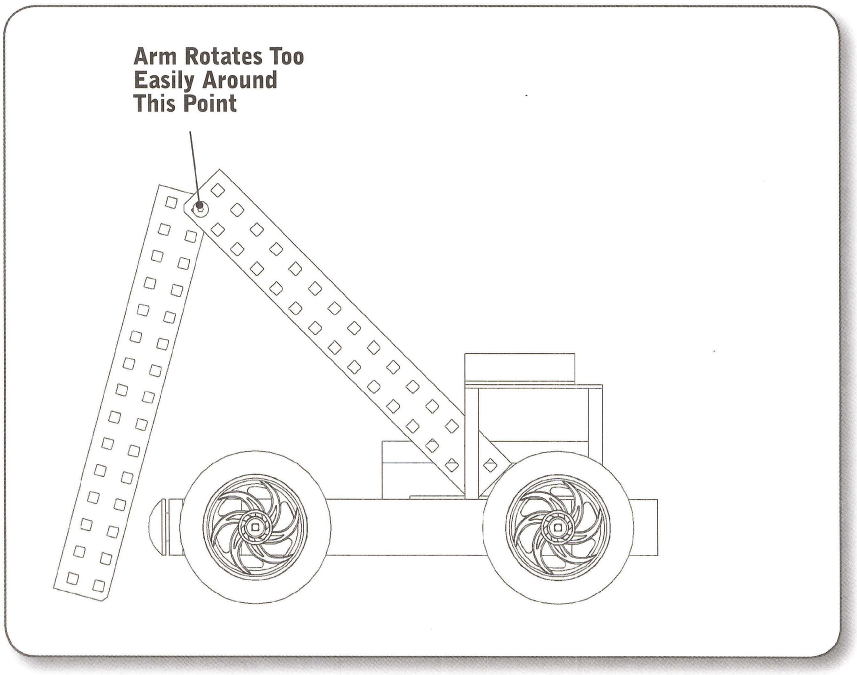
concepts to understand, continued

Sturdiness

Fasteners
There are over a hundred screws in your starter kit. Use them! The most common problems with robots that fall apart or lose pieces easily is not that individual parts come apart or bend, but rather that groups of parts are not joined securely enough, and separate from each other or move around.

EXAMPLE 1:
Arm Extension
A robot needs to be able to reach a goal that is high off the ground. The goal is so high that a single long piece will not reach it. Two pieces must be joined together to reach the desired height.



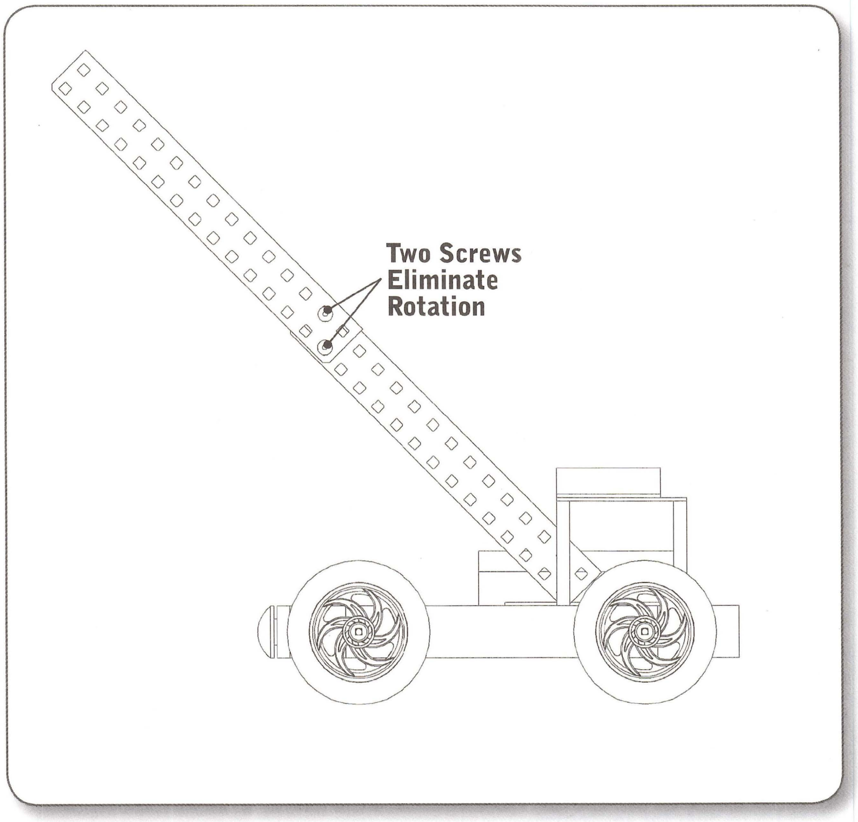


concepts to understand, continued

Sturdiness, continued

EXAMPLE 1, continued: Arm Extension, continued
This attachment uses a single screw to join the two bars. As you can see, it has a problem when weight is applied to it: the extension bar rotates around the screw. Also, if this screw were to come loose or fall out for any reason, the entire arm would come crashing down.

By using two screws, this design removes the possibility of rotation around either one of them. Additionally, the design is much more resilient, and can maintain its shape to a limited extent even if one of the two screws were to come loose or fall out.

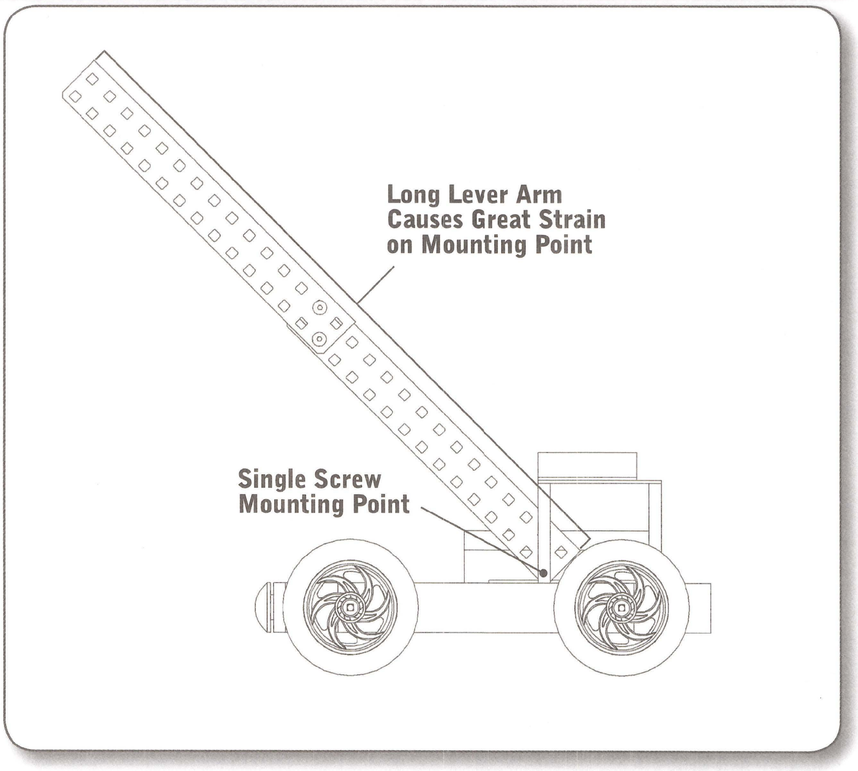


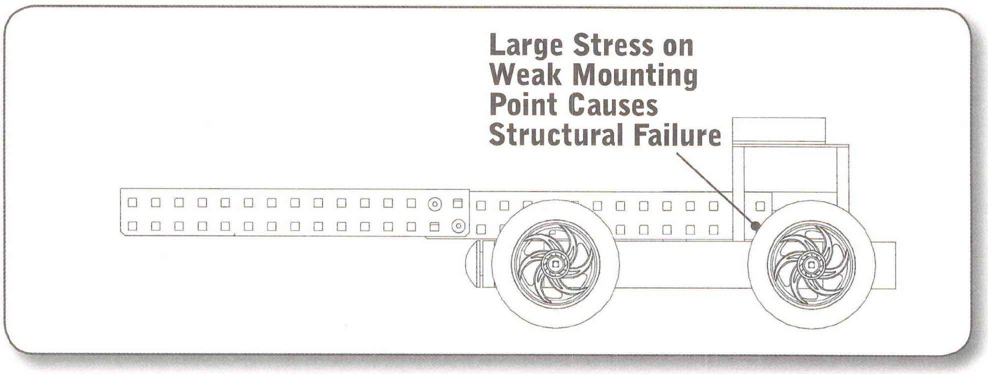
concepts to understand, continued

Sturdiness, continued

EXAMPLE 2:
Bracing
The extended bars are now attached firmly to each other, and the long arm is mounted on your robot. However, the long arm is liable to generate huge stresses at its mounting point because it is so long, especially when the force is applied near the end.

In order to keep the arm from falling back down, you will need to brace it. You could use a second screw to hold it, like you did with the arm itself, but because the arm has so much mechanical advantage from its length (it is effectively a lever), that screw would actually be in danger of deforming or breaking. A better solution would be to give the structure support at a point closer to the end, thus reducing the mechanical advantage that the arm has relative to the supports.


Long Lever Arm Causes Great Strain on Mounting Point
Single Screw Mounting Point

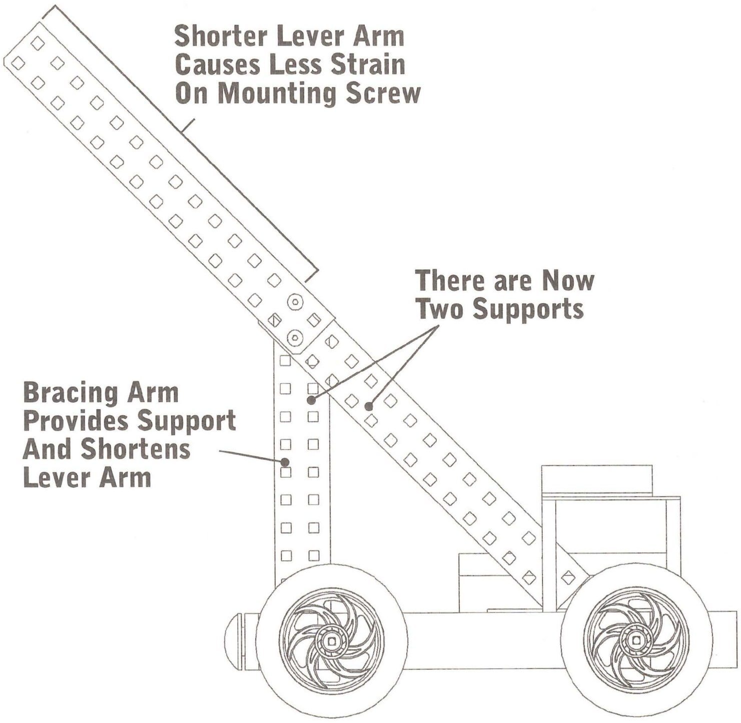

Large Stress on Weak Mounting Point Causes Structural Failure

concepts to understand, continued

Sturdiness, continued

EXAMPLE 2:
Bracing the Bars, continued

The arm is now more stable and better able to withstand stresses placed on it from both its own weight, and any external forces acting on it. It has both decreased the mechanical advantage from the long lever arm, and spread the load over two supports instead of just one.


Shorter Lever Arm Causes Less Strain On Mounting Screw
There are Now Two Supports
Bracing Arm Provides Support And Shortens Lever Arm

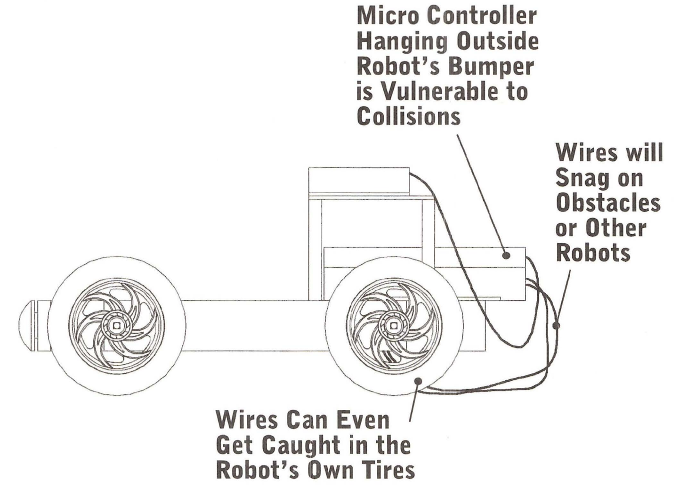
concepts to understand, continued

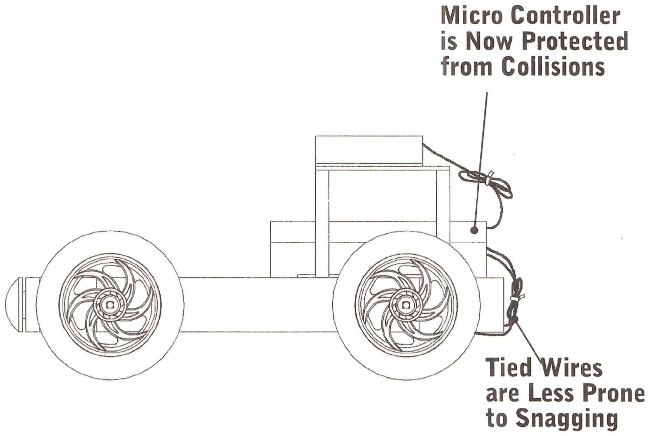
Exposure and Vulnerability

There are certain parts of a robot that are more fragile than others. Always plan the structural design to protect these parts from unwanted physical contact if possible.

The design in the example at the right is asking for trouble. The Vex Micro Controller is a sensitive piece of electronic equipment, and it can be a poor design decision to put it somewhere like this where it could be damaged by a simple physical impact. In particular, this design leaves the back of the Vex Micro Controller exposed in such a way that a passing robot or a careless driver could smash the entire rear connector panel, potentially damaging the radio control and power connections. Also, the wires are a mess. This is dangerous, because if one of those wires were to snag on another robot (or even on the robot's own wheels!), the connector would be forcibly removed from its port. Not only would this disable the robot on the field, but it could cause permanent damage to the cable or the ports on the Vex Micro Controller.

Adjusting the position of the controller so that it is not likely to get hit by anything, and cleaning up the wires (the kit comes with wire ties) reduce the chance of damage to the sensitive electronic components on the robot. As a bonus, it looks a lot cleaner as well.


Micro Controller Hanging Outside Robot's Bumper is Vulnerable to Collisions
Wires will Snag on Obstacles or Other Robots
Wires Can Even Get Caught in the Robot's Own Tires


Micro Controller is Now Protected from Collisions
Tied Wires are Less Prone to Snagging

subsystem interactions

How does the Structure Subsystem interact with...

...the Motion Subsystem?

- The motion and structure subsystems are tightly integrated in many robots designs, including the Squarebot. The motion subsystem can't be constructed without certain structural components (like the chassis rails) to provide support and positional reference. By the same token, the structure subsystem must be designed largely to accommodate the motion components.
- On Squarebot, the structure and motion subsystems are so interconnected that you cannot build them separately. Hence, they are constructed together in the Squarebot chassis assembly instructions.

...the Power Subsystem?

- The structure subsystem generally provides a safe, protected place to secure the battery.
- On the Squarebot, the structure subsystem provides a mounting platform for the battery holder, on the upper deck of the chassis (see Power Subsystem building instructions).

...the Sensor Subsystem?

- The structure subsystem provides a mounting and stabilization platform for sensors on the robot. Often, sensors need to be held in a specific position to function properly, and the structural subsystem must be designed to accommodate these needs.
- On the Squarebot, the structure subsystem provides a mounting spot for the bumper switch sensors, where they can detect collisions from the front and rear.

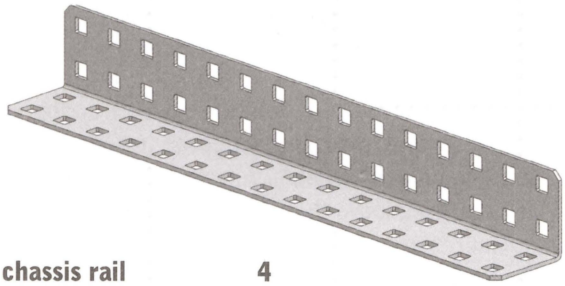
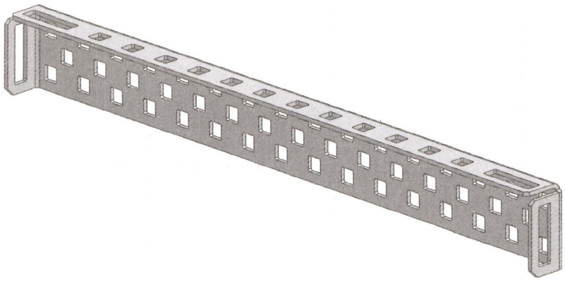
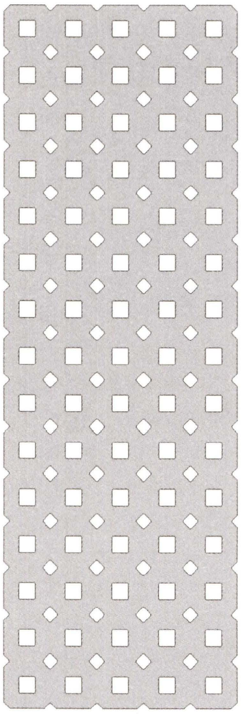
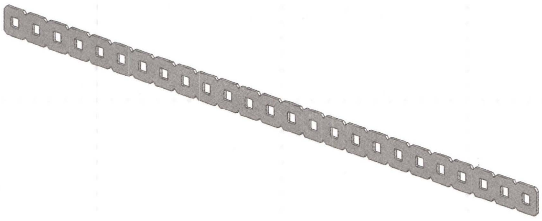
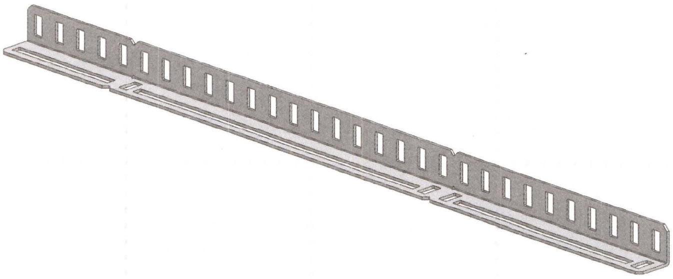
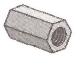
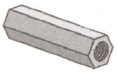
...the Control Subsystem?

- The structure subsystem will generally provide a place to store the RF Receiver module on the robot. In some cases, you will need to construct a piece to hold the antenna wire in a safe place, or to hold it up above the robot to extend its signal range.
- On Squarebot, the structure subsystem provides an elevated deck for the RF receiver module and antenna holder to be mounted for enhanced reception.

... the Logic Subsystem?

- The structure subsystem holds the Micro Controller in place. Since the Micro Controller is a very delicate and important part of the robot, the structure subsystem will also need to provide physical protection for the Micro Controller by keeping it in a secure spot.
- The structure subsystem does not plug into the Micro Controller in any way; however, the structure subsystem does need to provide accommodation and protection for the wires that run between the Micro Controller and other pieces.
- On the Squarebot, the structure subsystem provides a mounting platform for the Micro Controller module, and a place to tie wires down.

structure subsystem inventory

component	qty	
chassis bumper	2	
chassis rail	4	
panel	2	
long bar	4	
long angle bar	4	
fully threaded beams (½")	10	
fully threaded beams (1")	8	

structure subsystem inventory, continued

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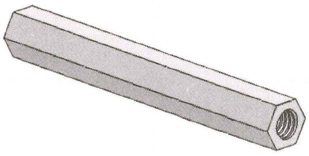
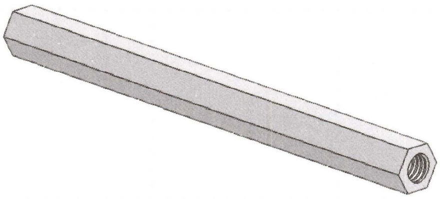
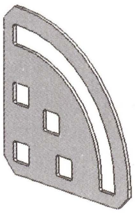
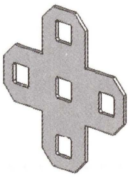
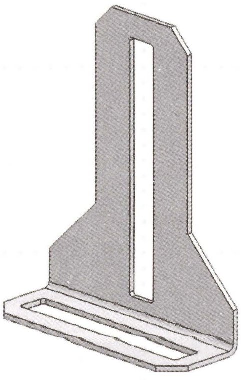
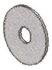
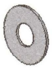
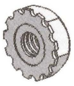
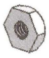
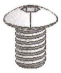
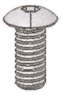
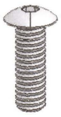
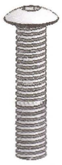
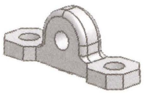
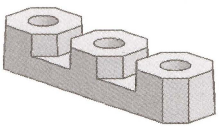
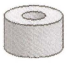
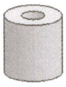
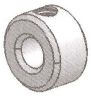
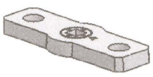
partially threaded beams (2") 	4
partially threaded beams (3") 	4
pivot 	2
plus gusset 	2
gusset 	2

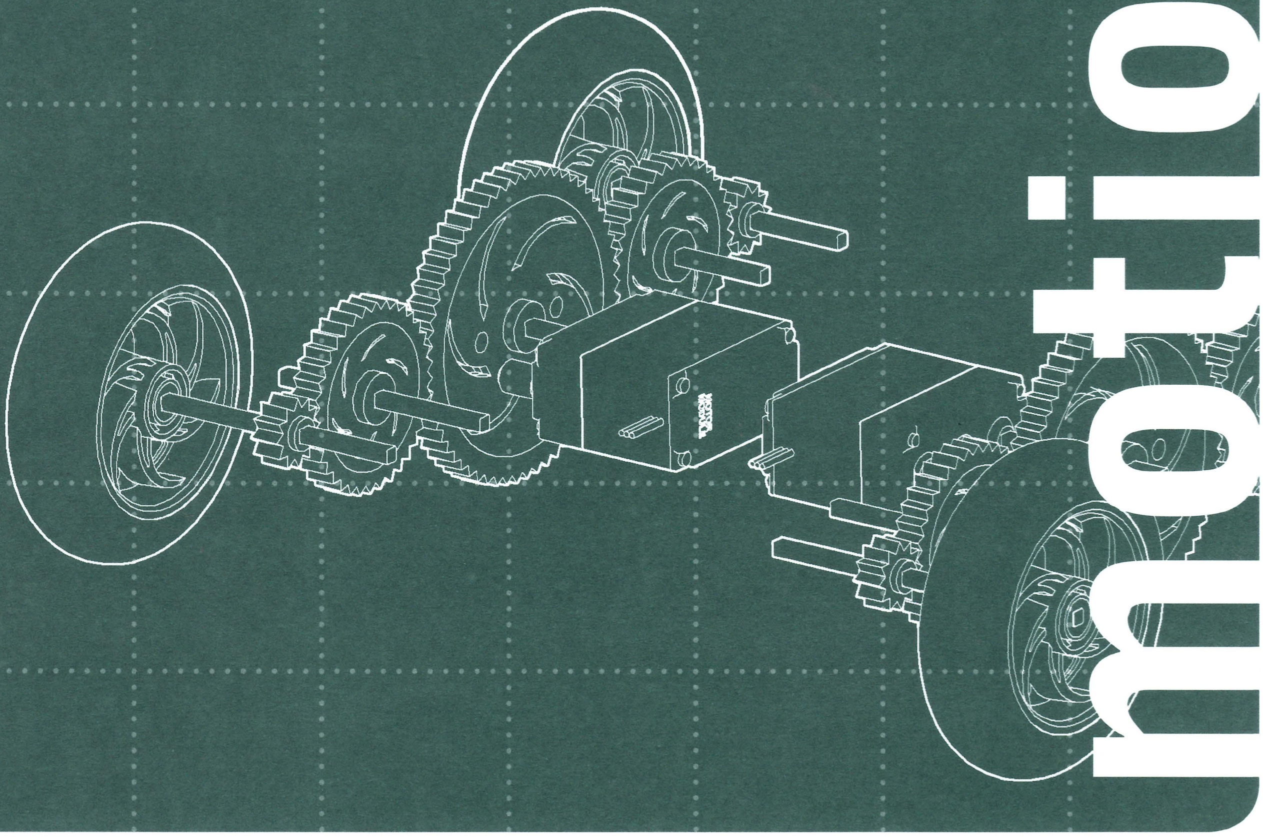
component	qty
washer, steel 	30
washer, delrin 	10
keps nut (¼") 	65
lock nut (¼") 	14
screw 8-32 x ¼" 	70
screw 8-32 x ⅜" 	28
screw 8-32 x ½" 	28
screw 8-32 x ¾" 	14

structure subsystem inventory

component	qty
bearing block 	6
bearing flat 	16
0.182" plastic spacer 	20
0.318" plastic spacer 	20
collar 	16
threaded screw for collar 	16
lock plate 	4

motion

The motion subsystem of the robot is responsible for exactly that, motion. It includes both the motors that generate motion, and the wheels and gears that transfer and transform that motion into the desired forms. With the structural subsystem as the robot's skeleton, the motion subsystem is its muscle.



motion

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squarebot assembly

In the Squarebot design, the Motion Subsystem is tightly integrated with the Structure Subsystem. The two systems are built together to form the "Chassis" of the Squarebot.

Refer to the Squarebot Chassis Parts and Assembly section in the Structure chapter to see how the Motion and Structure subsystems are built in tandem.

concepts to understand

Motors and Servomotors

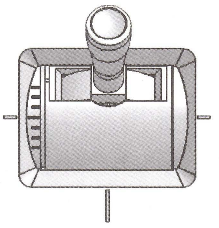
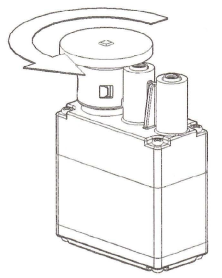
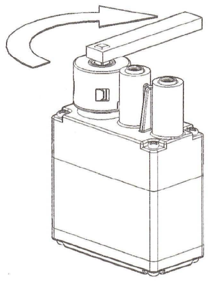
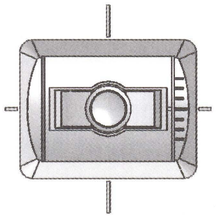
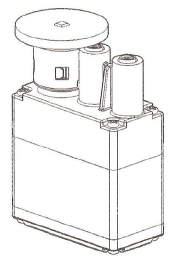
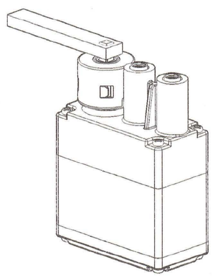
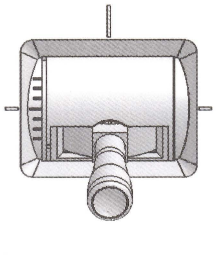
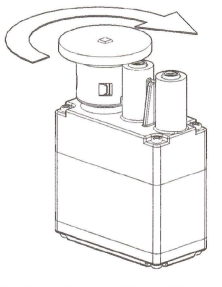
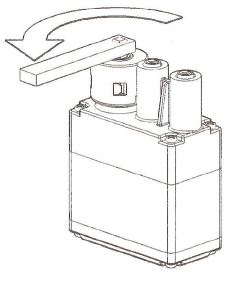
Motors are devices that can transform electrical energy into mechanical energy. That is, they take electrical power, and create physical motion. In the VEX system, they are further divided into two main types: standard motors and servomotors.

The main difference is very clear and straightforward. Standard motors spin the attached axle around and around, while servomotors turn the axle to face a specific direction within their range of motion (120 degrees for the Vex servo module).

Note also that the Vex motor modules and Vex servo modules rotate their shafts in opposite directions, given the same transmitter command. This minor difference is due to the internal motor designs of the two different modules.

For more information on radio control operation, see the Control Subsystem section of the Inventor's Guide.

Components

TRANSMITTER COMMAND	MOTOR BEHAVIOR	SERVOMOTOR BEHAVIOR
		
		
		

concepts to understand, continued

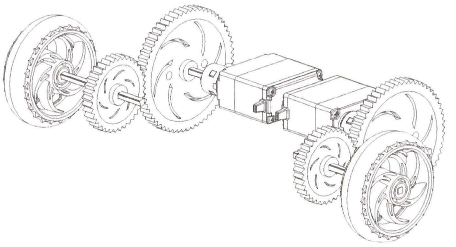
Motors and Servomotors, continued

Using Motors and Servos
While similar in appearance, motors and servomotors are suited to distinctly different types of tasks.

Regular motors should be used whenever continuous rotation is needed, such as in a robot's main drive system.

Servomotors can only be used in cases where the boundaries of motion are well-defined, but have the invaluable ability to self-correct to maintain any specific position within those boundaries.

Motor Example: Main Drive Motors

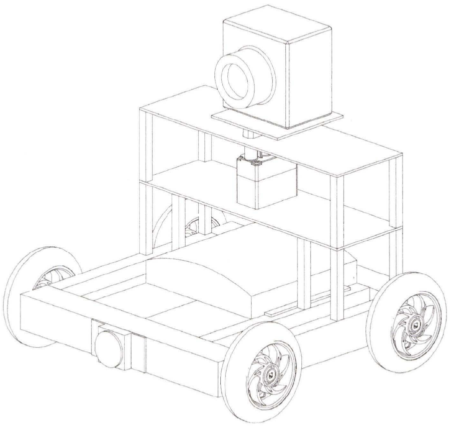


Use regular motors to power the robot's drive wheels. The wheels need to make continuous full rotations, which is exactly the kind of motion provided by the motors.

Servomotor Example: Directable Attachment Mounting

Use a servomotor to control the facing of a platform on top of the robot (shown with a wireless camera for illustrative purposes).

The servomotor allows you to turn the platform to face a specific direction relative to the robot, and will automatically hold that position until the controls are released.



Speed vs. Torque

A motor can generate a set amount of power; that is, it can provide a specific amount of energy every second—this energy is most commonly used to make a wheel spin. Since there is only so much energy to go around, however, there is an inherent trade-off between ***Torque***—the force with which the motor can turn the wheel—and ***Speed***—the rate at which the motor can turn the wheel.

The exact configuration of torque and speed is usually set using gears. By putting different combinations of gears between the motor and the wheel, the speed-torque balance will shift.

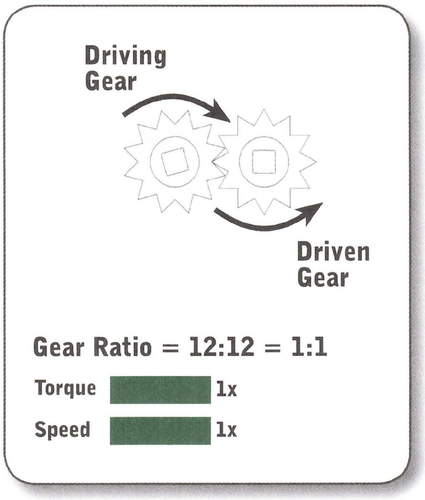
Gears

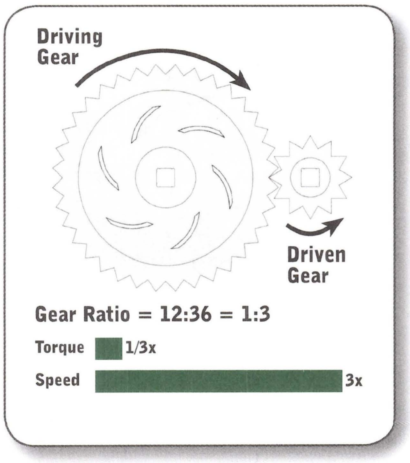
Gear Ratio

You can think of gear ratio as a "multiplier" on torque and a "divider" on speed. If you have a gear ratio of 2:1, you have twice as much torque as you would if you had a gear ratio of 1:1, but only half as much speed.

Calculating the gear ratio between a pair of gears is simple. First, identify which gear is the "driving" gear, and which is the "driven" gear. The "driving" gear is the one that is providing force to turn the other one. Often, this gear is attached directly to the motor axle. The other gear, the one that the driving gear is turning, is called the "driven" gear.

To find gear ratio, you just need to count the number of teeth on the "driven" gear, and divide it by the number of teeth on the "driving" gear.


Driving Gear
Driven Gear
Gear Ratio = 12:12 = 1:1
Torque
1x
Speed
1x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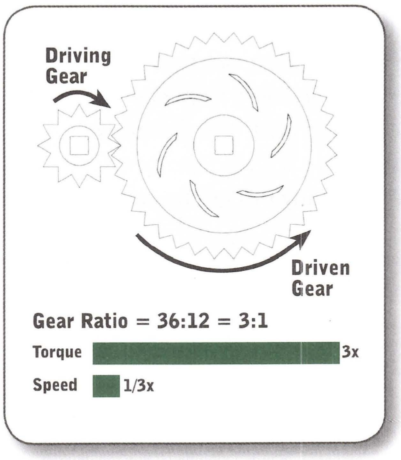
Driven Gear
Gear Ratio = 12:36 = 1:3
Torque
1/3x
Speed
3x


Driving Gear
Driven Gear
Gear Ratio = 36:12 = 3:1
Torque
3x
Speed
1/3x

concepts to understand, continued

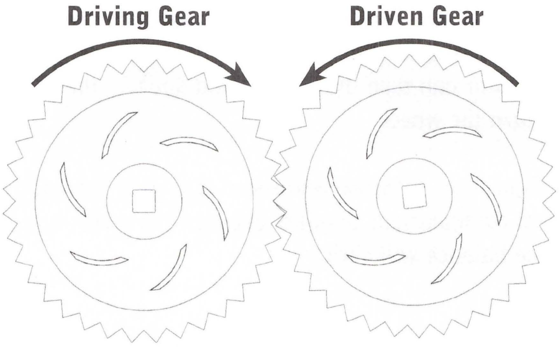
Gears, continued

Idler Gears
Gears can be inserted between the driving and driven gears. These are called idler gears, and they have no effect on the robot's gear ratio because their gear ratio contributions always cancel themselves out (because they are a driven gear relative to the first gear, and a driving gear relative to the last gear—you would first multiply by the number of teeth on the idler gear and then divide by the same number, which always cancels out).

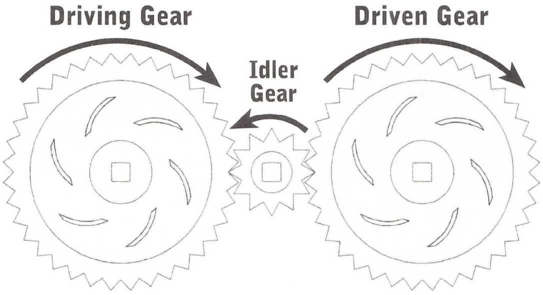
However, idler gears do reverse the direction of spin. Normally, the driving gear and the driven gear would turn in opposite directions. Adding an idler gear would make them turn in the same direction. Adding a second idler gear makes them turn in opposite directions again.

Idler gears are typically used either to reverse the direction of spin between two gears, or to transmit force from one gear to another gear far away (by using multiple idler gears to physically bridge the gap).

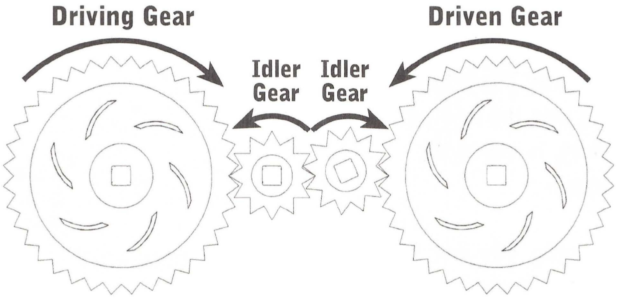
No Idler



One Idler



Two Idlers

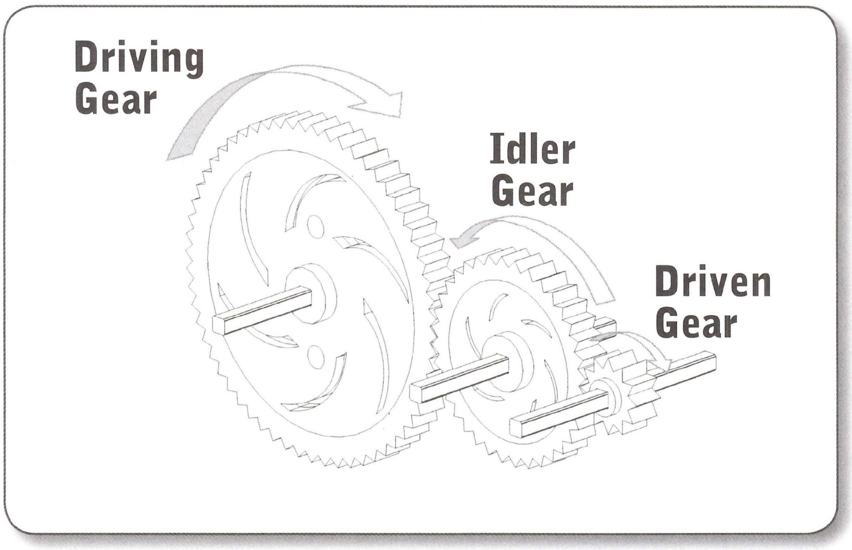


01/31/05

concepts to understand, continued

Gears, continued

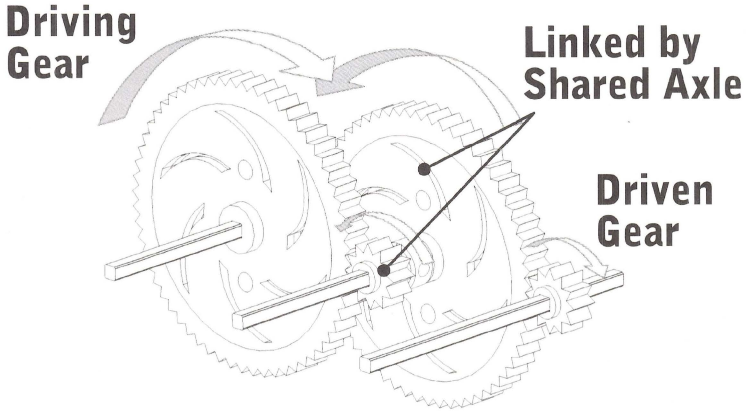
Compound Gear Ratio
Compound gears are formed when you have more than one gear on the same axle. Compound gears are not to be confused with idler gears, as compound gears can affect the overall gear ratio of a system!



In the compound gear system, there are multiple gear pairs. Each pair has its own gear ratio, but the pairs are connected to each other by a shared axle.

The resulting compound gear system still has a driving gear and a driven gear, and still has a gear ratio (now called a "compound gear ratio").

The compound gear ratio between the driven and driving gears is then calculated by multiplying the gear ratios of each of the individual gear pairs.



Compound Gear Ratio:
12:60 x 12:60 = 1:5 x 1:5 = 1:25

Compound gears allow configurations with gear ratios that would not normally be achievable with the components available. In the example above, a compound gear ratio of 1:25 was achieved using only 12 and 60-tooth gears. This would give your robot the ability to turn an axle 25 times faster than normal (though it would only turn with 1/25th of the force)!

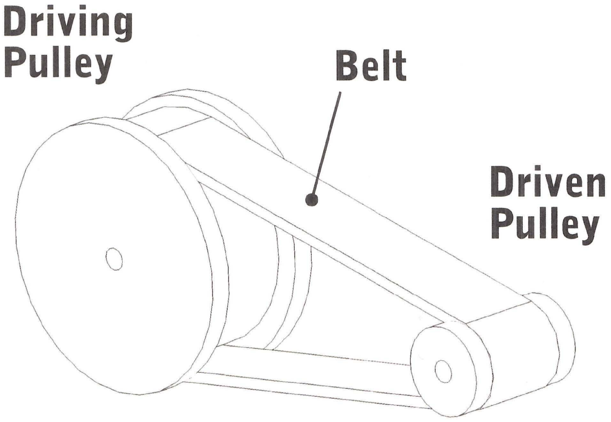
concepts to understand, continued

Gears, continued

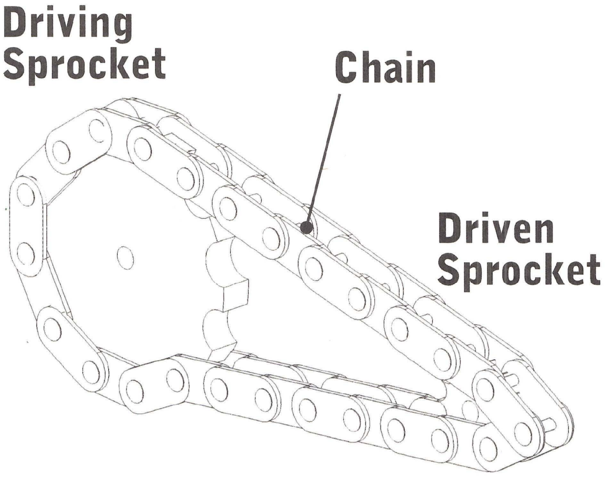
Gear ratio with non-gear systems
The real nature of gear ratios is a little more complex than just counting teeth on gears. Gear ratio is actually defined as the number of rotations that the driving axle needs to make in order to turn the driven axle around once. When dealing with toothed gears, you can find the number of turns needed by counting teeth, as you have already seen above (see "Gear ratio").

With other types of systems, you can still find the "gear ratio" by measuring the number of rotations on the driven and driving axles. Some of these other drive types include belt-and-pulley drives and chain-and-sprocket drives.

Belt or chain drives are often preferred over gears when the motor and the wheel are located far apart on the robot. However, both belts and chains introduce their own special maintenance and performance requirements into the system (chains require lubrication and tension, for instance), and you should carefully weigh their advantages against other design considerations.



Belt Drive



Chain Drive

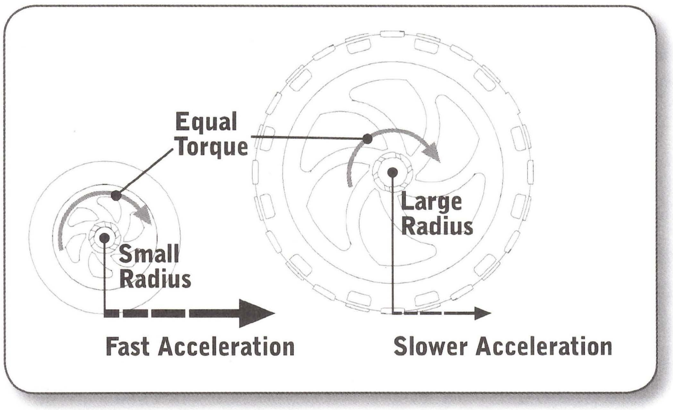
concepts to understand, continued

Wheels

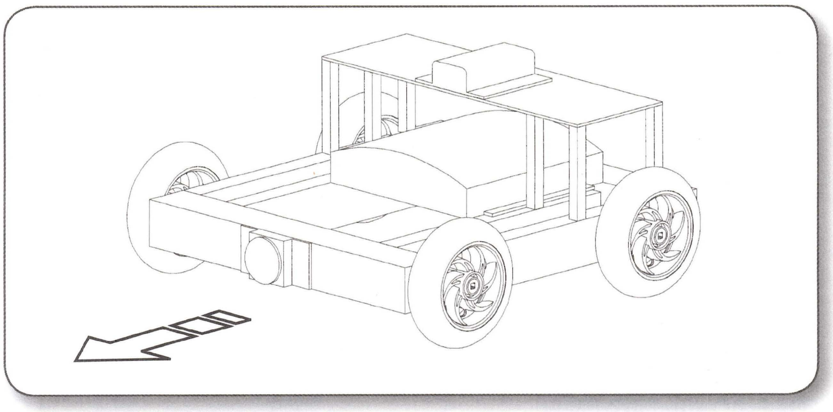
Wheel Sizes
Often, the role of the motion subsystem on a robot will be to move the robot along the ground. The last step in the drive train, after the motors and gears, is the wheels.

Like motors and gears, different properties of the wheel will affect your robot's performance. The size of the wheels will be an important factor here, and will affect two distinct and different characteristics of the robot: its acceleration, and its top speed.

Wheel Sizes and Acceleration
The relationship between wheel size and acceleration is simple: bigger tires give you slower acceleration, while smaller tires give you faster acceleration.



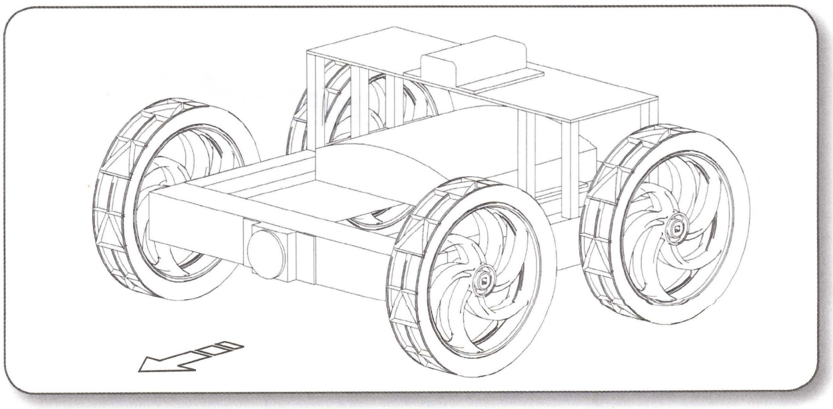
This relationship is the product of the physics of converting the spinning motion of a motor into the forward motion of the vehicle.



Motors generate a "spinning" force (torque), which wheels convert into a "pushing" force at the point where they contact the ground. The larger this "pushing" force is, the faster the robot will accelerate.

The relationship between torque and force is:

$$\text{Force} = \frac{\text{Torque}}{\text{Distance from Center to Edge of Wheel}}$$



A longer distance between the center of the wheel and the ground will produce a smaller force for the same amount of torque, hence the larger wheel (which has the longer distance) has a smaller force, and hence the slower acceleration.

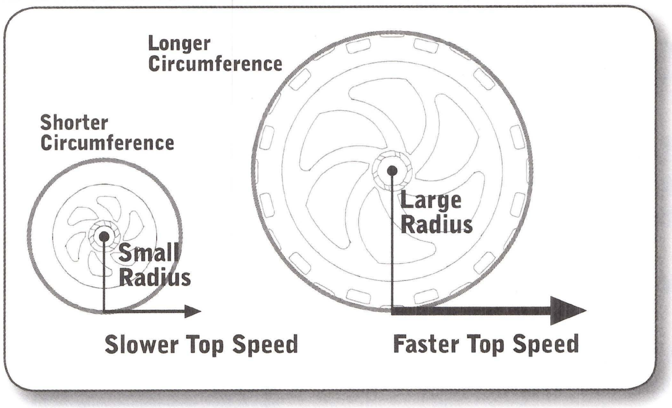
concepts to understand, continued

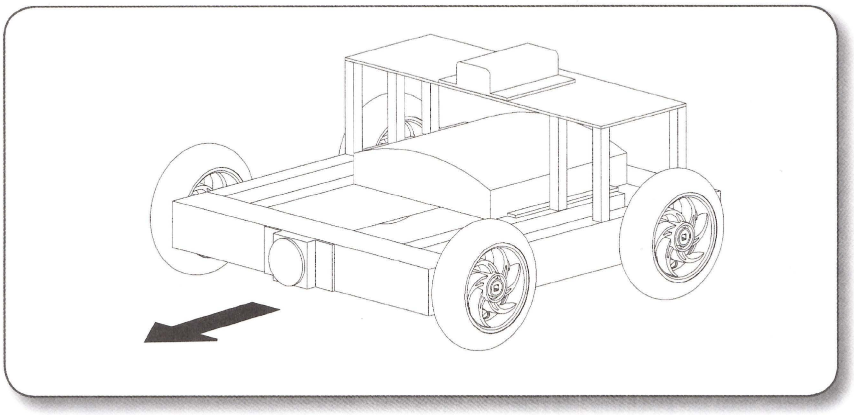
Wheels, continued

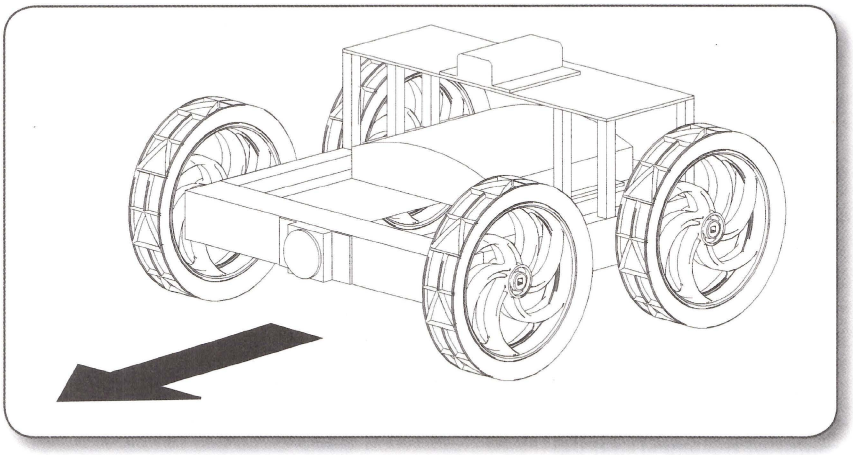
Wheel Sizes and Top Speed
At top speed, robots with the same motor and gear ratio will generally travel with the motor running at the fastest speed it can spin. Robots may take some time to reach this speed, especially if they have high gear ratios (high gear ratio = low torque), but eventually, they tend to reach it, or at least come close.

When a wheel rolls along the ground, it is effectively "unrolling" its circumference onto the surface it is traveling on, every time it goes around. Larger wheels have longer circumferences, and therefore "unroll" farther per rotation.

Putting these two observations together, you can see that a robot with larger wheels will have a higher top speed. The robot with larger wheels goes farther with each turn of the wheels, and at top speed, robots with the same motor and gears will have their wheels turning the same number of times per second. Same number of turns times more distance per turn equals more distance, so the robot with larger wheels goes faster.







Notice that this sets up a tough design decision, since you need to decide on a balance between acceleration and top speed when choosing a tire size. You can't have it both ways, so you'll need to plan ahead, decide which is more important to your robot, and choose wisely.

01/31/05

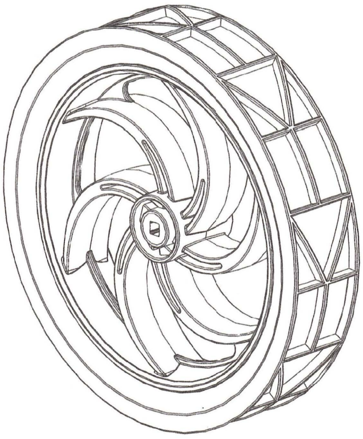
Wheels, continued

Friction

Friction occurs everywhere two surfaces are in contact with each other. It is most important when considering the wheels for your robot, however, because you will need to decide how much of it you want in order to maximize your robot's performance.

Wheel friction has both positive and negative consequences for your robot. On the one hand, friction between the wheel and the ground is absolutely essential in getting the robot to accelerate. Without friction, your robot would spin its wheels without going anywhere, like a car stuck on a patch of ice. Friction between the wheels and the ground gives the robot something to "push off" of when accelerating, decelerating, or turning.

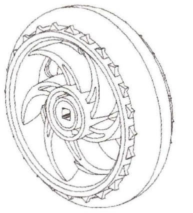
On the other hand, wheel friction is also responsible for slowing your robot down once it is moving. A robot running over a sticky surface will go slower than one running over a smooth one, because the friction dissipates some of the robot's energy.



All-Purpose Tire

Speed 🟩🟩🟩🟩🟩🟩🟩 **Medium**

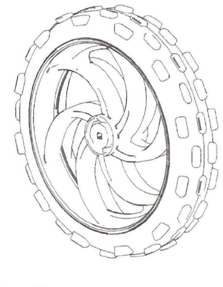
Traction 🟩🟩🟩🟩🟩🟩🟩 **Medium**



Smooth Tire (hub only)

Speed 🟩🟩🟩🟩🟩🟩🟩🟩🟩🟩

Traction 🟩 **Slippery**



Knobby Tire

Speed 🟩 **Slower**

Traction 🟩🟩🟩🟩🟩🟩🟩🟩🟩🟩

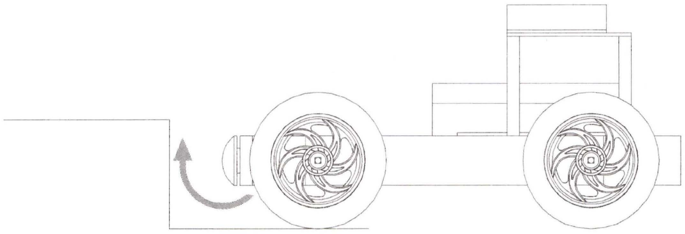
The width, texture, and material of a tire all contribute to its friction characteristics. Wider, bumpier, or stickier tires will have more friction. Narrower, smoother, or slipperier tires will have less friction. Again, there is no "best" solution. Rather it is a matter of picking the tire best suited to the robot's task.

concepts to understand, continued

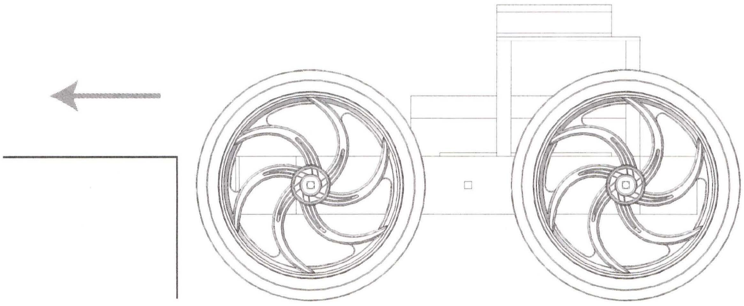
Wheels, continued

Terrain
On more difficult challenge courses, there will often be physical obstacles that must be traversed. Both the size of a tire and the amount of friction it generates will be very important in ensuring that you can successfully navigate them. These obstacles will be numerous and complex, so you will need to plan for them, and test your solutions to make sure that they work reliably.

Example 1:
Robot attempting to climb a step



The robot with smaller wheels has a much steeper angle to climb – in fact, it's a sheer vertical face.

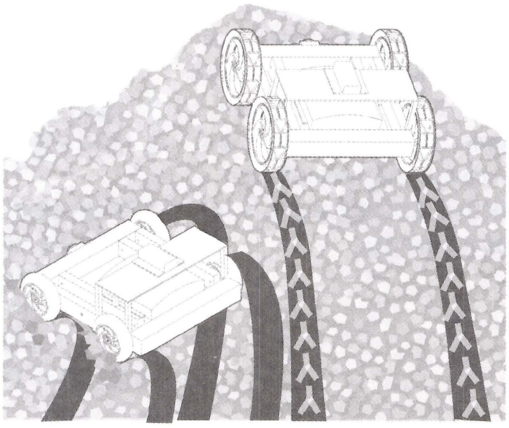


The robot with larger wheels has a much less difficult angle to climb to get up the step. This robot is much more likely to succeed.

Example 2:
Robots attempting to climb a gravel hill

The robot with slippery tires cannot get enough traction to climb the hill and slides off.

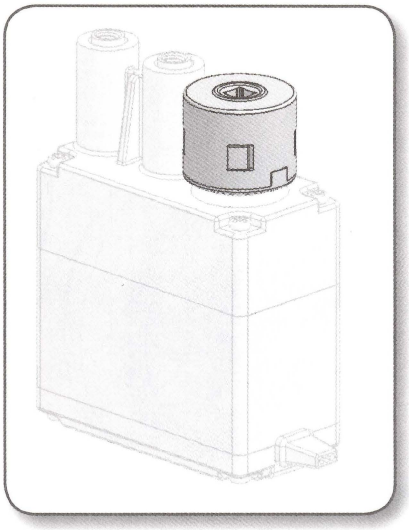
The robot with better traction can make it up the hill.



concepts to understand, continued

Clutches

Clutches
Every motor in the Vex Starter Kit comes with a pre-attached clutch module. The clutch module's purpose is to prevent damage to the motor's internal gearing by temporarily breaking the connection between the motor and its attached wheel or gear whenever there is too much resistance. This prevents the motor from entering the potentially damaging stall (motor can't turn) or back-driving (motor is being forced backwards) conditions.

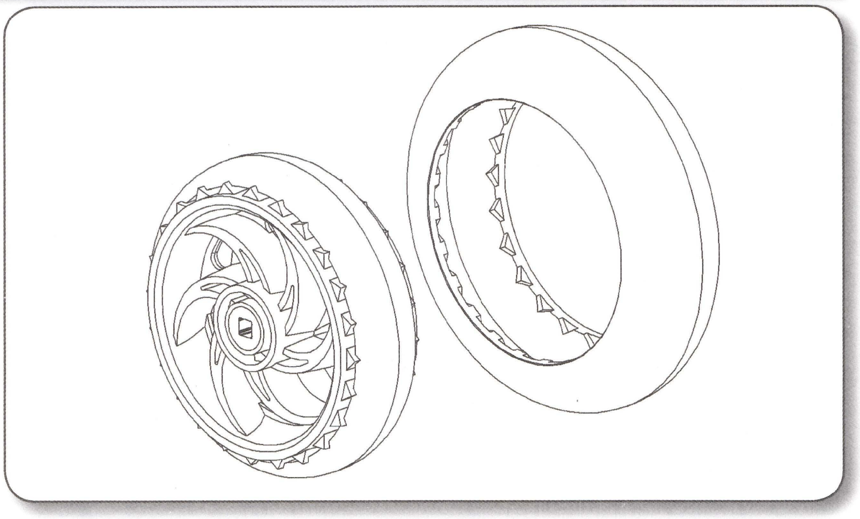


The motor clutches are removable for maintenance reasons, but should always be replaced immediately afterwards. Do not attempt to operate the motors without the clutches installed.

concepts to understand, continued

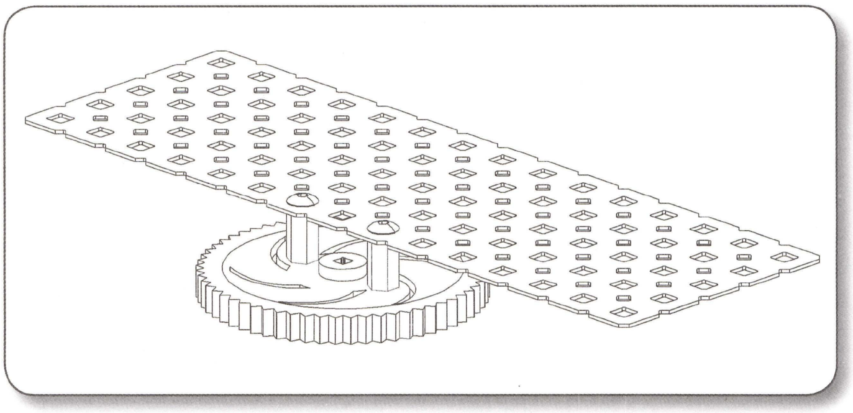
Motion Part Features

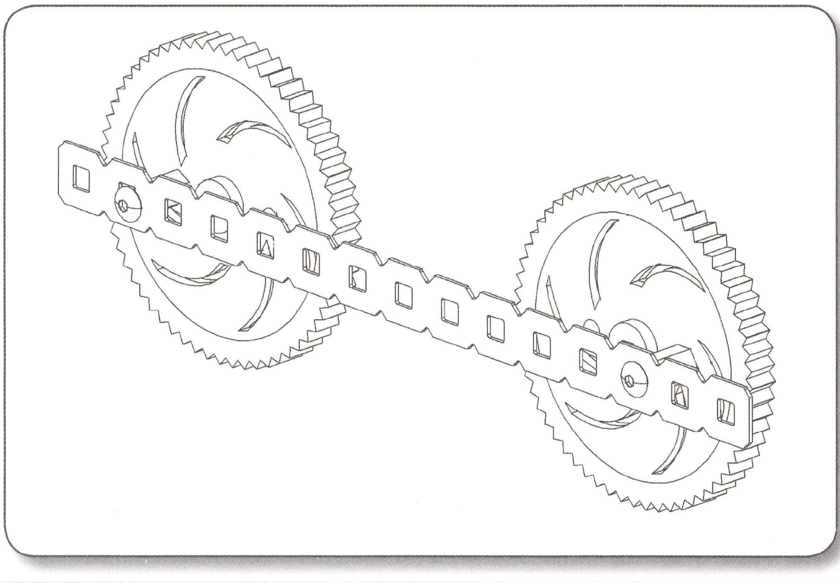
Hub Tire
The small green tires in the kit are actually two tires in one. By pulling off the rubbery green tire surface, the grey hubs can be used directly as a set of very small, low-friction tires for your robot.



Non-Axial Mounting Points (60-tooth gear)
In addition to the central hole for the gear shaft, the 60-tooth gear (and 84-tooth gear, available separately) have a number of additional off-center mounting holes.

These mounting points have a number of applications. For instance, a larger structure could be built on top of the gear, which would rotate as the gear turned. Alternately, the "orbiting" motion of a non-axial mount can be used to create linear motion from rotational motion.





Motor Gear Replacement

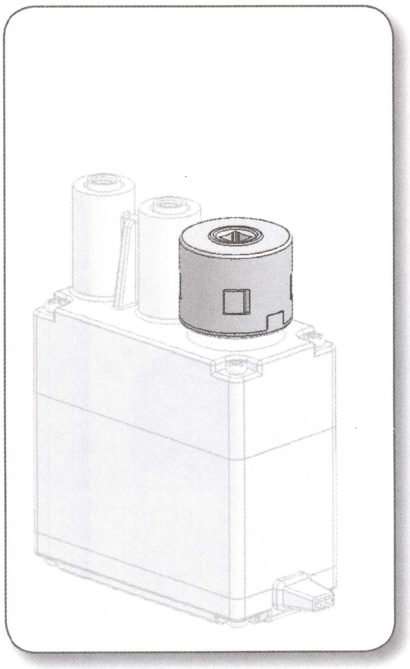
Gear Wear and Tear
Gears are simple plastic components, but they often bear tremendous amounts of stress in a moving system. The gears inside the motors, in particular, are subjected to large amounts of wear and tear during use in robotics applications where they are frequently required to reverse direction quickly (to make the robot go the other way, for instance).

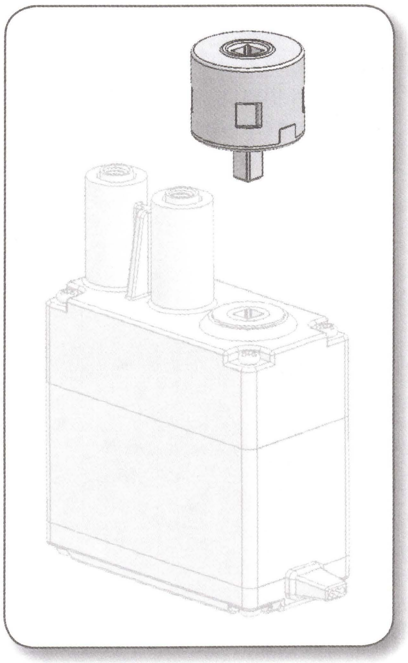
Inevitably, these gears will wear out and need replacement. The Vex Starter Kit includes replacement gears for the internal motor gears (and you can buy more), so you can perform the necessary repairs when needed.

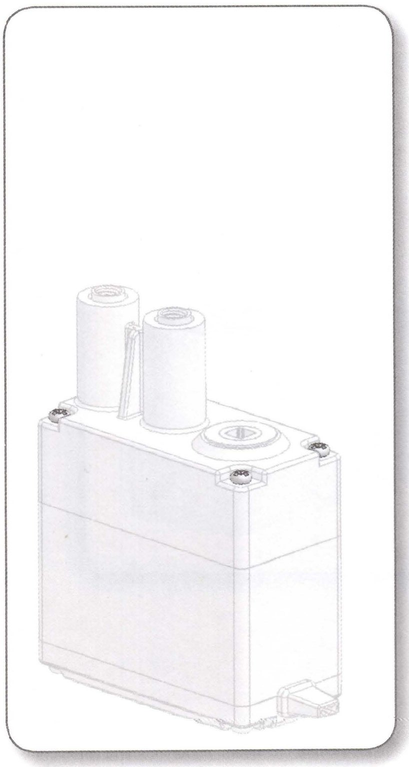
To replace the gears in a motor or servomotor, follow these instructions.

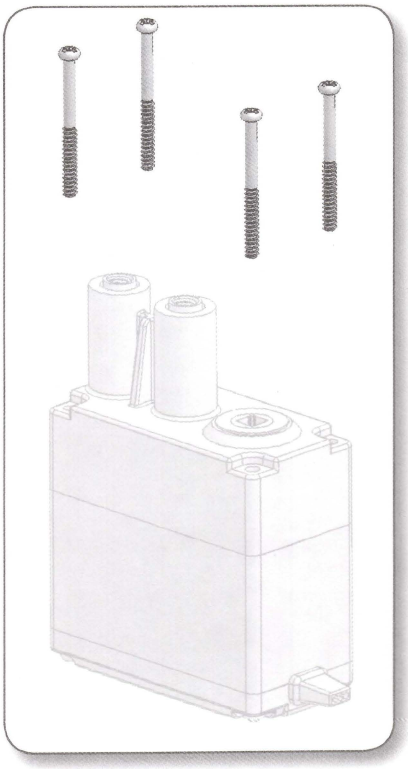
1. (top of page) Remove the clutch and clutch post.

2. Remove the four screws in the corners of the front of the motor case.



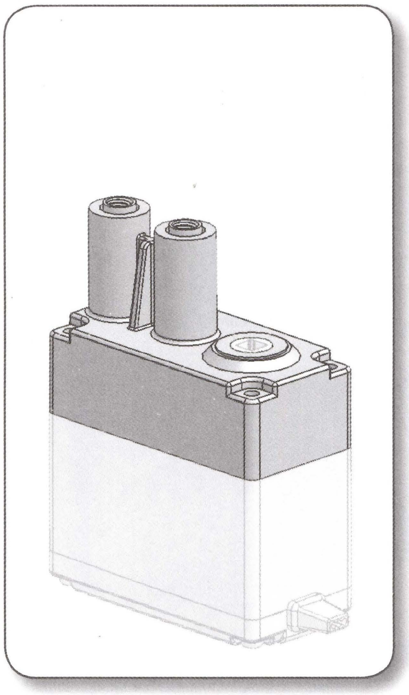


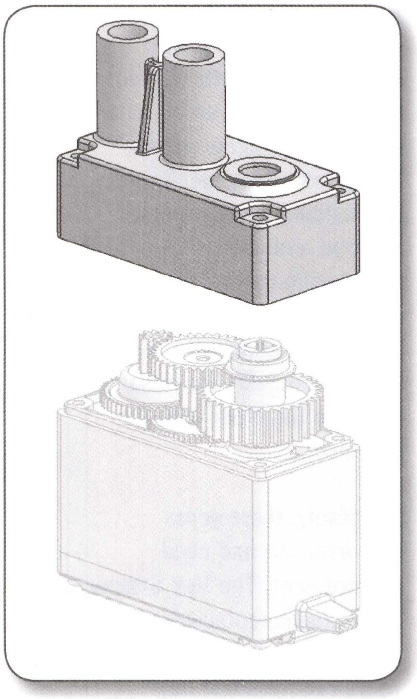




Motor Gear Replacement, continued

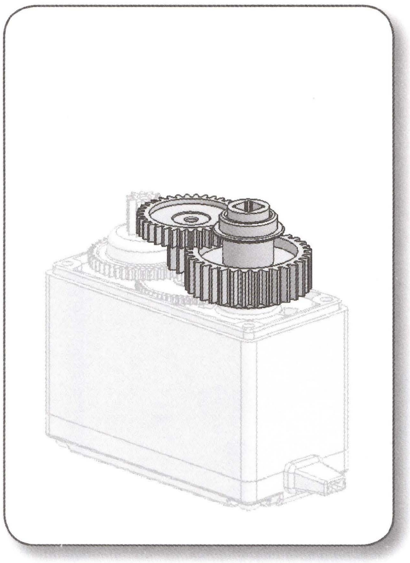
3. Gently lift off the top cover. Try to do so without disturbing the gears inside, so you can see the proper configuration for later reference.

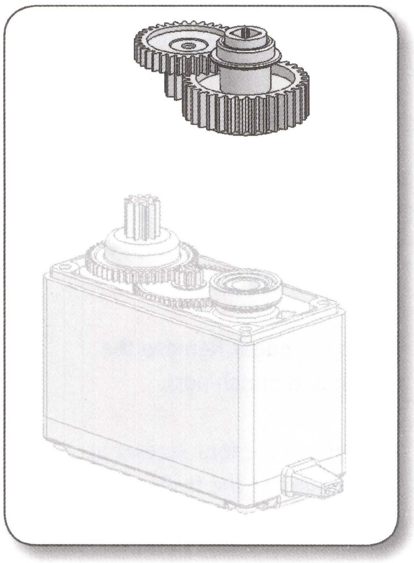




4. Remove the middle gear and the large shaft gear together.

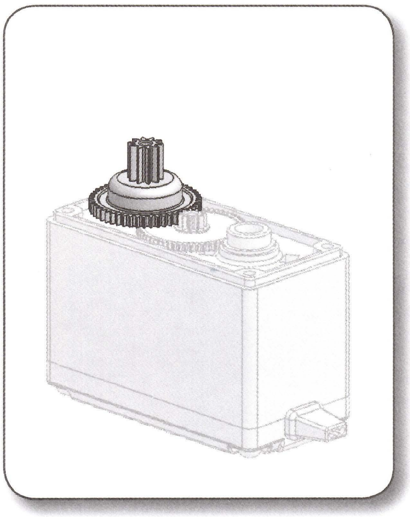
*Be careful when handling gears, as they are coated with a layer of lubricant that helps them turn smoothly. Wash your hands after handling the gears!

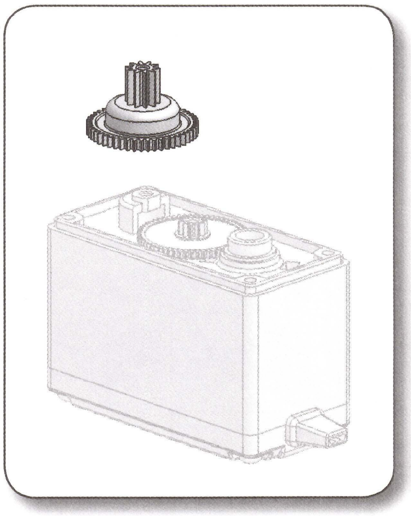




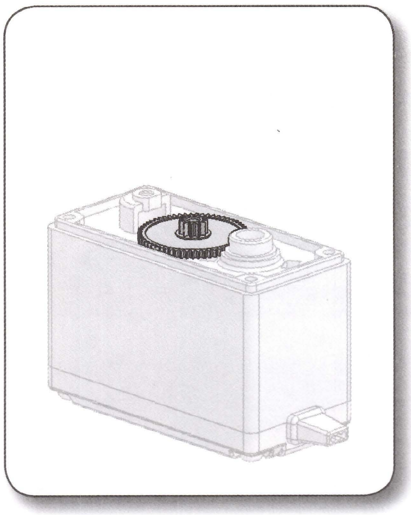
Motor Gear Replacement, continued

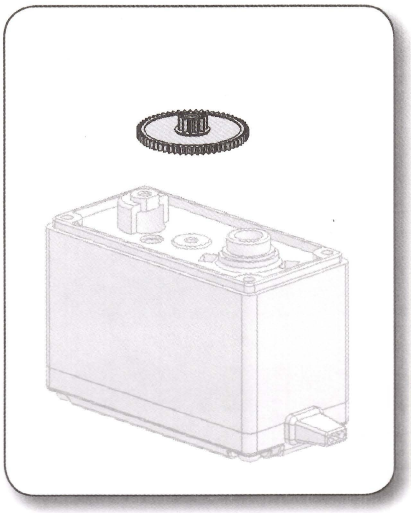
5. Remove the side gear.



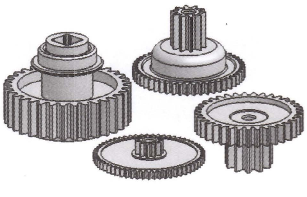


6. Remove the thin bottom gear.





7. Open the packaging for the replacement gears. Take special care when handling the replacement gears, as they are very small and slippery (they come pre-greased).

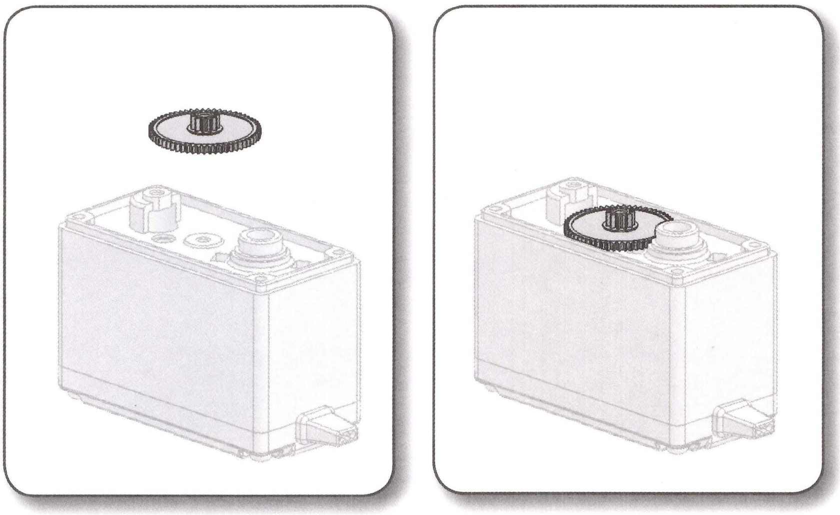


Note: The large black servo motor gear will have a black plastic key underneath the gear's metal bushing. (Not shown)

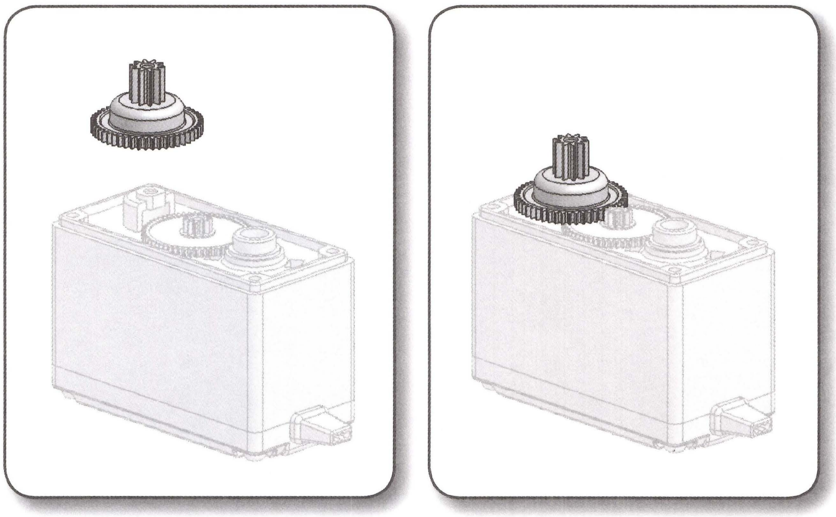
concepts to understand, continued

Motor Gear Replacement, continued

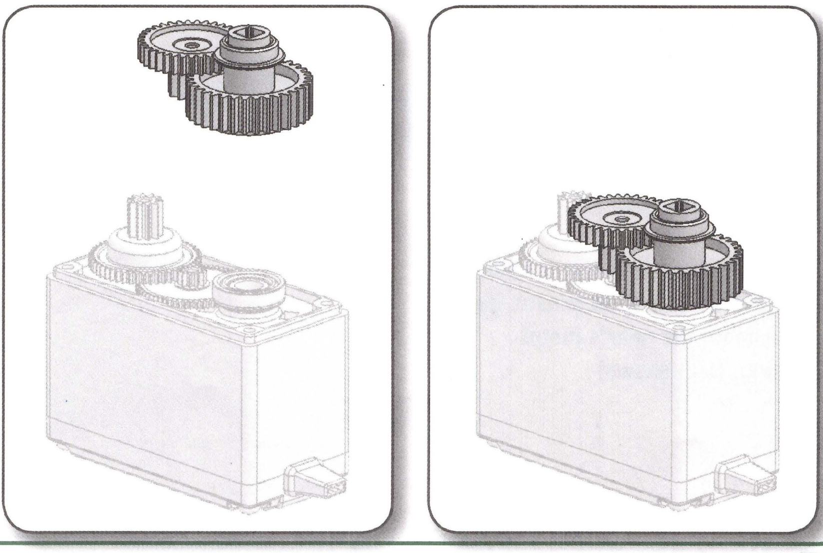
8. Install the replacement thin bottom gear.



9. Install the replacement side gear.

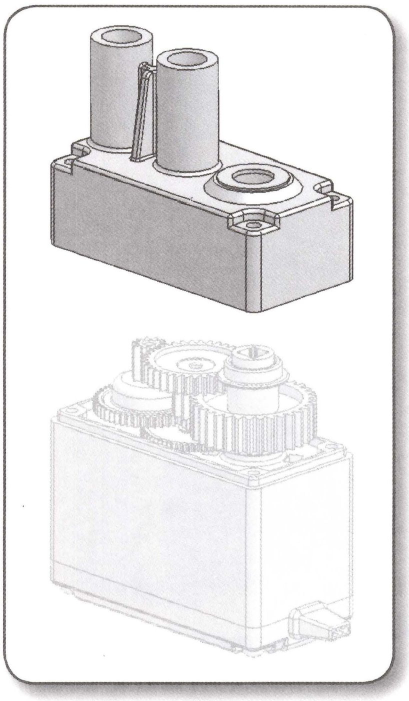


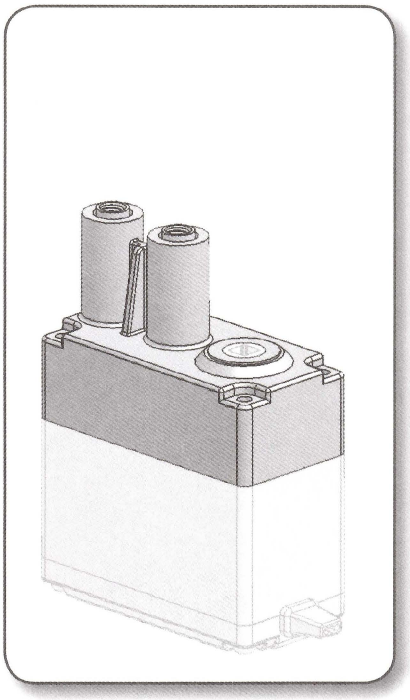
10. Install the replacement middle gear and the replacement large gear together, the same way you took them apart.



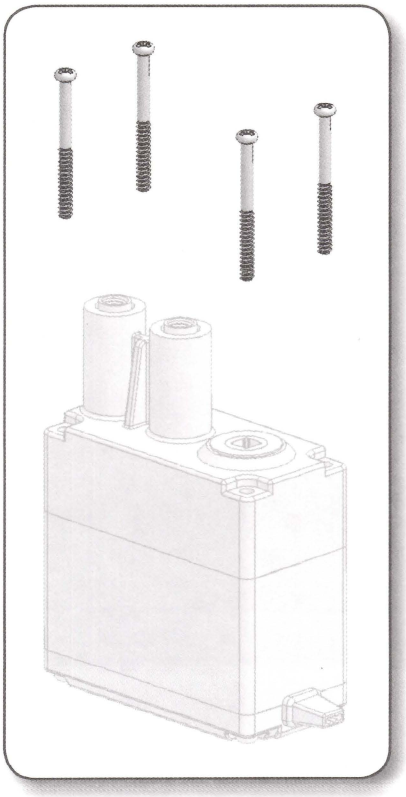
Motor Gear Replacement, continued

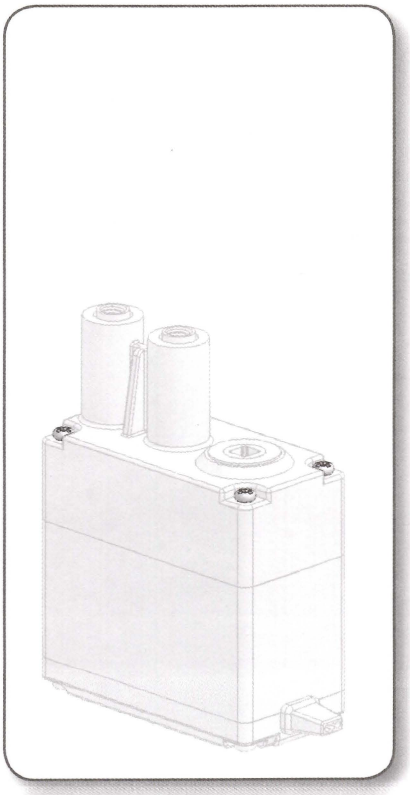
11. Carefully replace the top cover. Don't disturb the gears, or the motor may not turn properly.





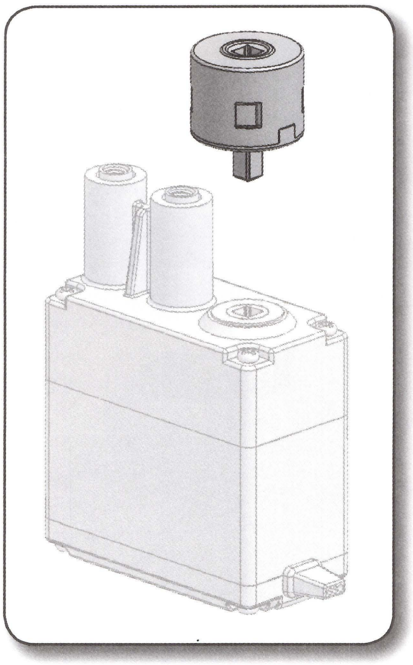
12. Replace the four corner screws.

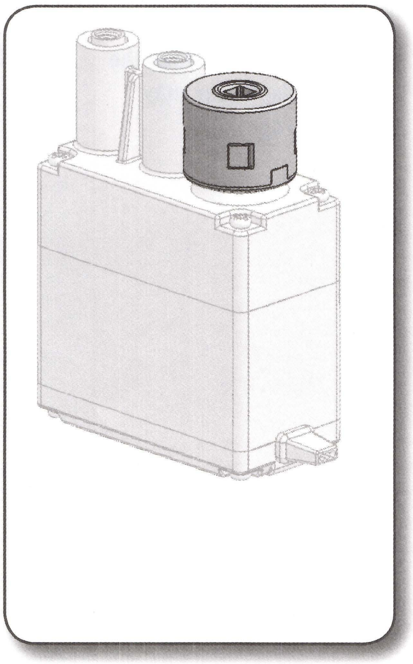




Motor Gear Replacement, continued

13. Replace the clutch and clutch shaft.





subsystem interactions

How does the Motion Subsystem interact with...

...the Structure Subsystem?

- The motion and structure subsystems are tightly integrated in many robots designs, including the Squarebot. The motion subsystem can't be constructed without certain structural components (like the chassis rails) to provide support and positional reference. By the same token, the structure subsystem must be designed largely to accommodate the motion components.
- On Squarebot, the structure and motion subsystems are so interconnected that you cannot build them separately. Hence, they are constructed together in the Chassis building instructions (which can be found in the Structure Subsystem chapter).

...the Power Subsystem?

- The Motion Subsystem's motors and servomotors convert electrical energy into physical energy, and so they will of course need electrical energy to work with. This energy is ultimately supplied by the Power Subsystem's batteries, but the motors do not plug into the batteries directly. Rather, the flow of power is directed by the Micro Controller, which decides how much power is allowed to flow from the Power Subsystem to the Motion components.

...the Sensor Subsystem?

- Robots often have motors and other Motion components controlled by sensors (for instance, the emergency stop function stops the motors when the bumper switch sensor is pushed). However, the Sensor Subsystem does not directly control the Motion Subsystem. Instead, the Sensors provide information to the Micro Controller, which takes that information into account, and then decides what command to send to the Motion Subsystem.

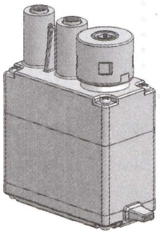
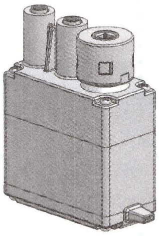
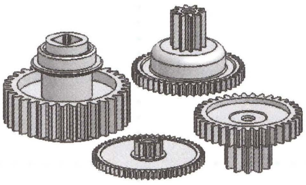
...the Control Subsystem?

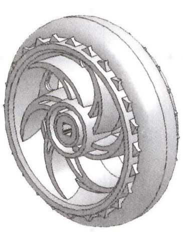
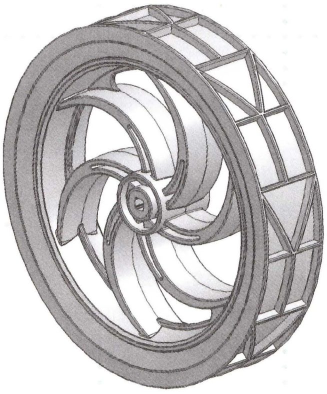
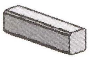
- Unlike radio-controlled cars, the Vex robot does not directly tie the Control Subsystem into the Motion Subsystem. The commands generated by the operator using the Transmitter are sent to the RF receiver on the robot, but from there, the commands are given to the Micro Controller, which takes this and other information into account when deciding which command to give to the Motion components.

... the Logic Subsystem?

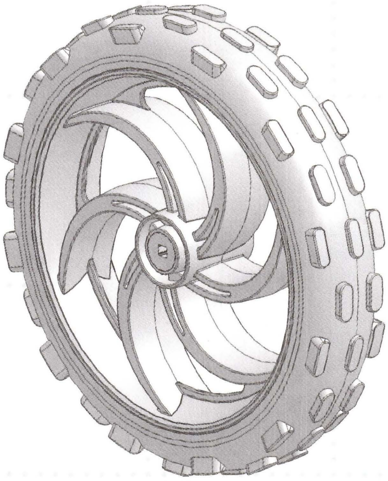
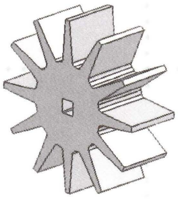
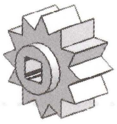
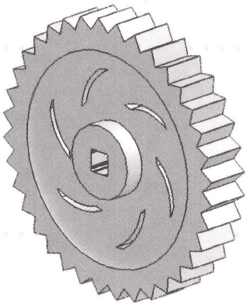
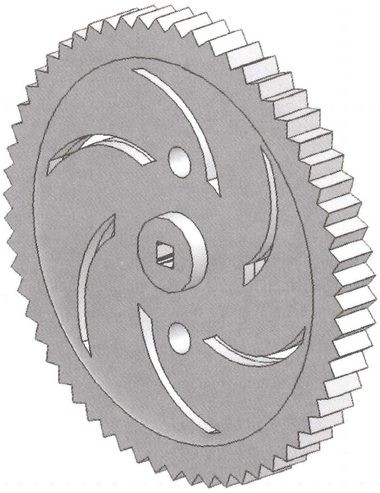
- The Motion Subsystem plugs into the Micro Controller, which is the main component in the Logic Subsystem. Though the Motion components are "controlled" to various degrees by user input (Control Subsystem) and sensor feedback (Sensor Subsystem), the final decision on what command is issued, as well as the actual flow of electricity (from the Power Subsystem) is all controlled by the Logic Subsystem. The Logic Subsystem governs everything the Motion components do.

motion subsystem inventory

component	qty
motor assembly 	3
servo motor 	1
replacement gears (4/set) 	2
screw 6-32 x ¼" 	4
screw 6-32 x ½" 	4

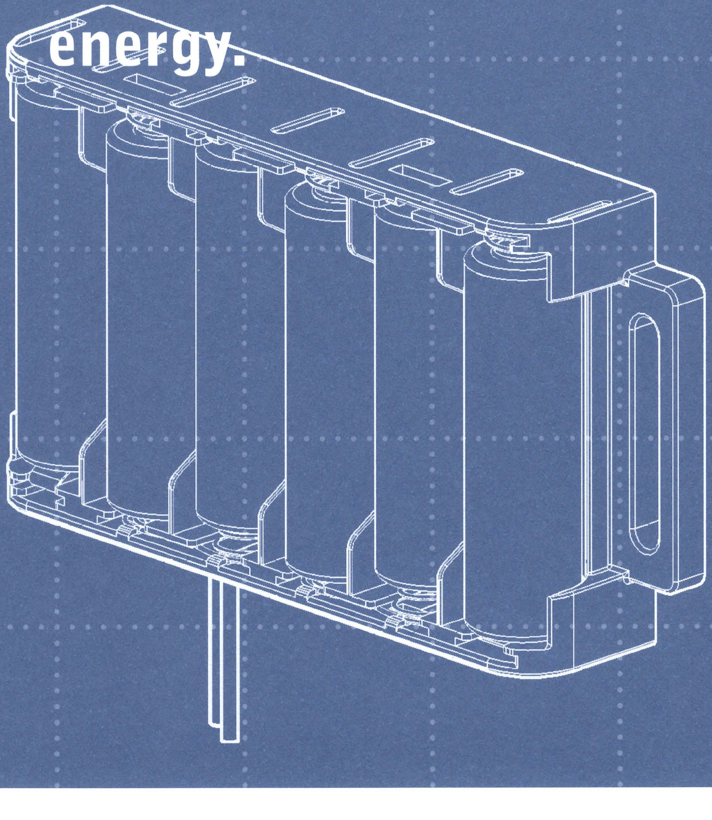
component	qty
2.75" removable tire 	4
1.895" hub for removable tire 	4
all purpose tire (4") 	4
clutch post 	4

motion subsystem inventory, continued

component	qty
knobby tire (5") 	2
intake roller 	2
12 tooth gear 	4
36 tooth gear 	4
60 tooth gear 	4

power

Power is vital to the operation of all the electronic parts on the robot, including the controller and the motors. With the structural subsystem as the robot's skeleton, and the motion subsystem as the muscle, the power subsystem is the circulatory system—the heart and blood vessels that provide the rest of the robot with energy.



power

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squarebot parts & assembly

Vex robots use batteries as their source of energy.
The power subsystem is comprised of batteries and the other components needed to support them.

Tips for battery use (see Battery Types and Battery Care in the Concepts to Understand section for details):

- Buy a Vex Power Pack or a good set of rechargeable AA batteries (more than one set if you want to be able to use the robot while the other set is charging)
- Buy a good battery charger
- Charge batteries fully before first use
- Dispose of batteries properly – not in the trash!

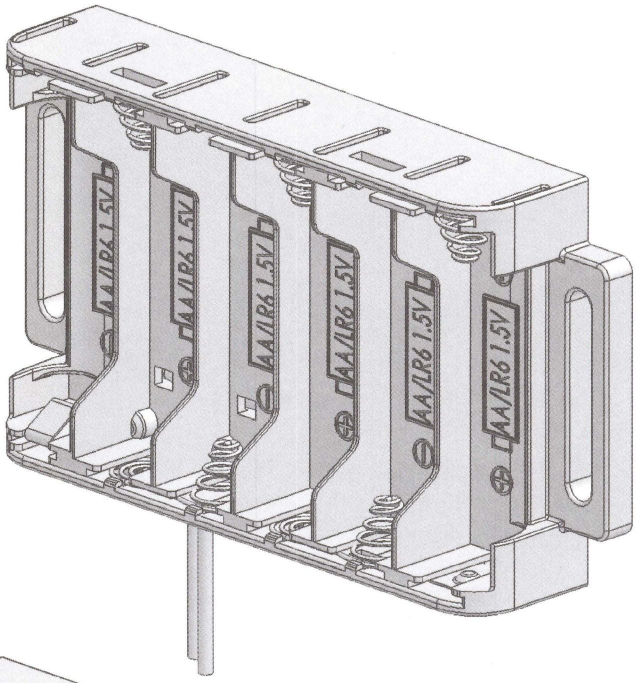
1 Collect and identify the parts from the list of materials below:

materials	qty
NiCd AA battery	14
battery holder with lid	1
transmitter battery box	1
keps nut	4
8-32 hex screw, $^3/_8$"	4

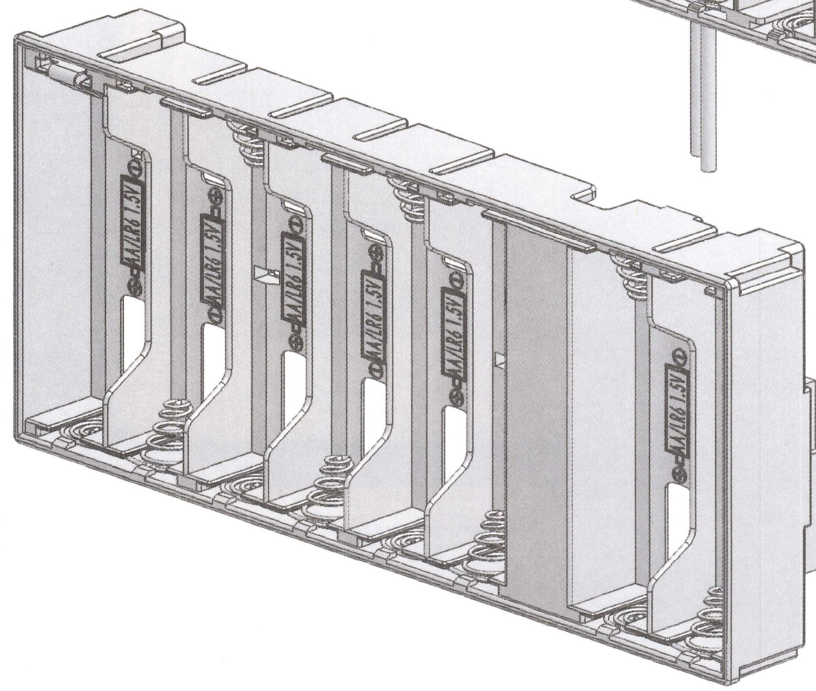
squarebot parts & assembly, continued

AA battery x 14

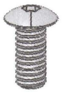
battery holder w/ lid x 1



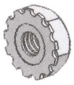
transmitter battery box x 1



8-32 hex screw, $^{3}/_{8}$" x 4



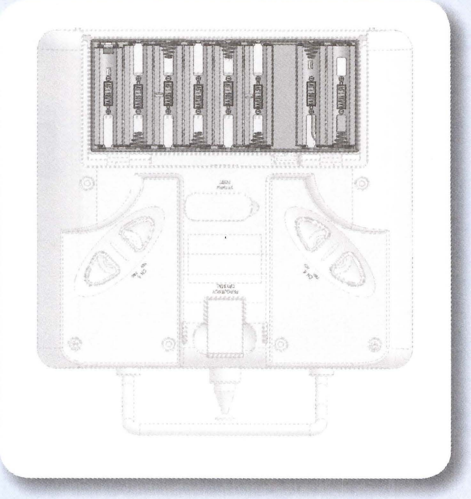
keps nut x 4



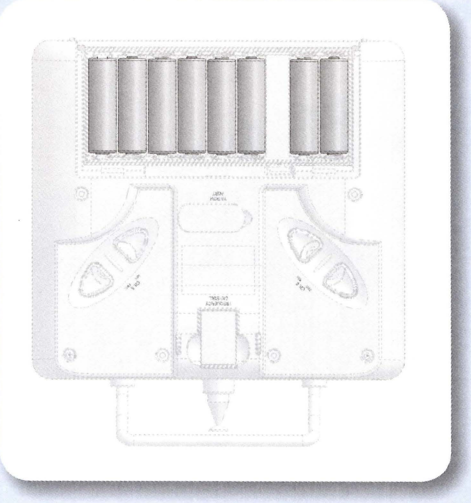
squarebot power parts and assembly, continued

2 **For Transmiter Assembly:**

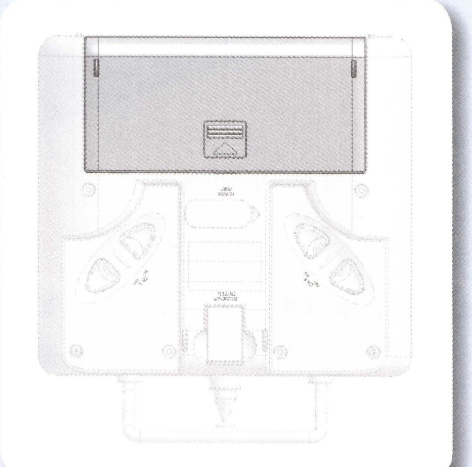
Open the battery lid.



Insert 8 AA batteries, paying close attention to the battery orientation indicated on the holder.

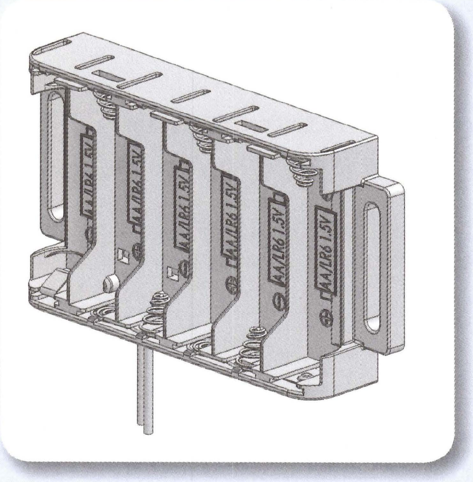


Close the lid.

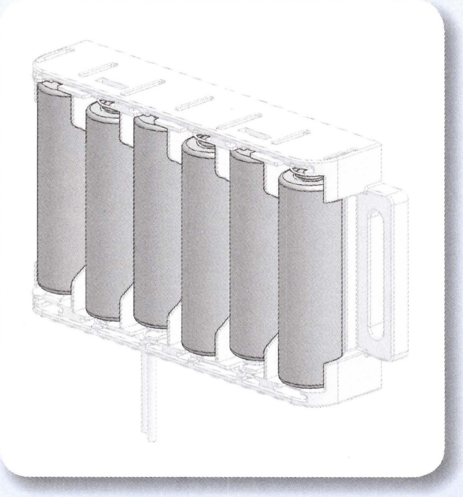


squarebot power parts and assembly, continued

3 For the Squarebot Battery Holder:
Remove the battery lid.


AA/LR6 1.5V
AA/LR6 1.5V
AA/LR6 1.5V
AA/LR6 1.5V
AA/LR6 1.5V
AA/LR6 1.5V

Insert batteries, paying close attention to the battery orientation indicated on the holder.

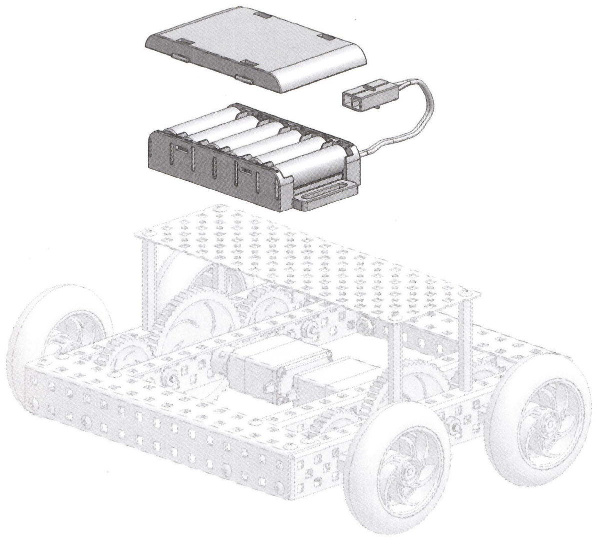


squarebot power parts and assembly, continued

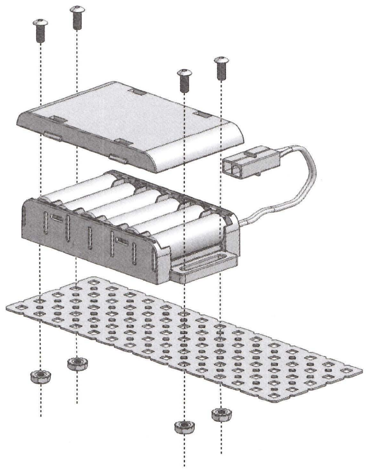
4 Positioning the Battery Holder on Squarebot:

Position the battery holder without the lid on top of the Squarebot.

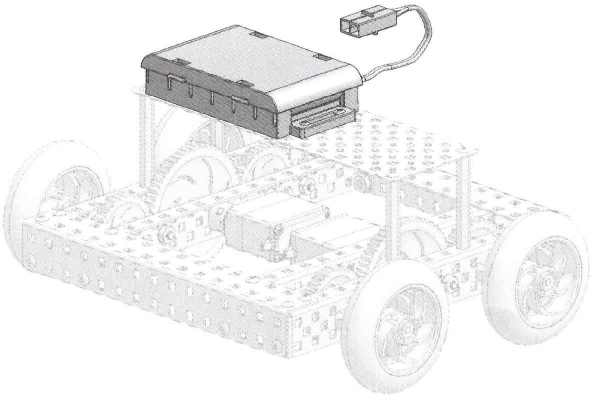
Keep the lid off until the screws that secure the holder are in place.



Attach holder using four 3/8" screws.



The final assembly should look like this:

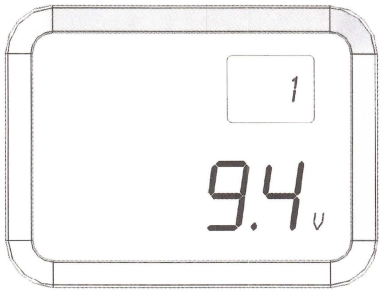


concepts to understand

Battery Power Indicators

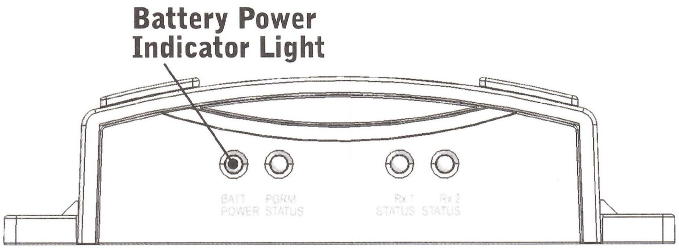
Since there are two sets of batteries in the Vex system, there are two battery power indicators.

One is on the Transmitter, and displays the battery voltage remaining in the transmitter unit.



Transmitter LED displayed voltage	**Indicates...**
9.4V	Transmitter batteries somewhat low. You will need to stop soon.
8.9V	Transmitter batteries very low (10 minutes or less remaining), stop unless absolutely necessary.
8.5V	Transmitter batteries depleted. Stop now.

The other indicator is the Batt. Power light on the front of the Micro Controller, which tells you when the batteries on board the robot need to be recharged.

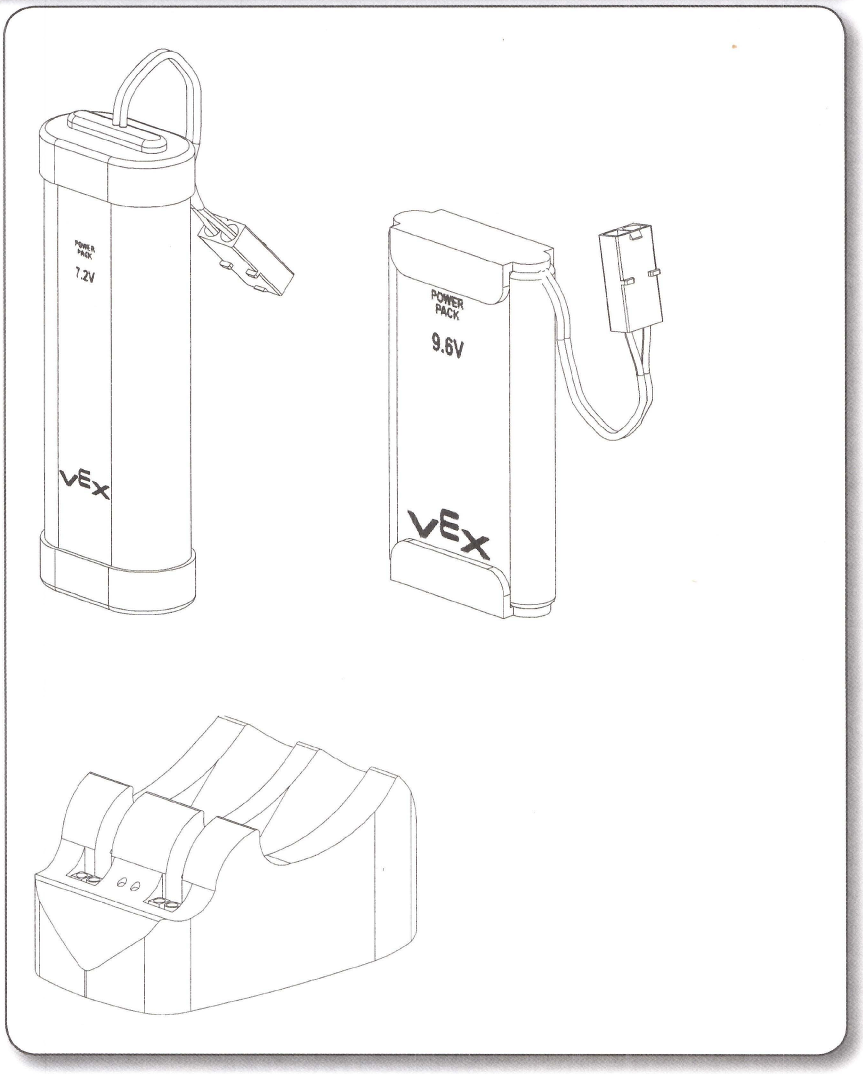


Battery Power Light Color	**Indicates...**
Green	Onboard robot batteries are OK.
Red	Onboard batteries need to be recharged.

concepts to understand, continued

Battery Types

Due to the large amount of current that the robot will draw from the batteries, we recommend NiCd batteries for use with the Vex robot.



VEX Power Pack

The best way to provide for the energy needs of the Vex robot is with the Vex battery. The Vex Power Pack includes a 7.2V battery pack for the robot, a 9.6V battery pack for the radio transmitter unit, and a charger for both batteries.

The batteries are NiCd (Nickel-Cadmium chemical composition) rechargeables that provide significantly energy than comparable AA NiCd batteries.

The Vex Power Pack cells, will provide a constant reliable voltage until they are exhausted. Contrary to popular belief, NiCd batteries do not suffer from any sort of permanent "memory effect" (see Battery Care later in this chapter).

For installation instructions, consult the documentation included with the Vex Power Pack.

concepts to understand, continued

Battery Types, continued

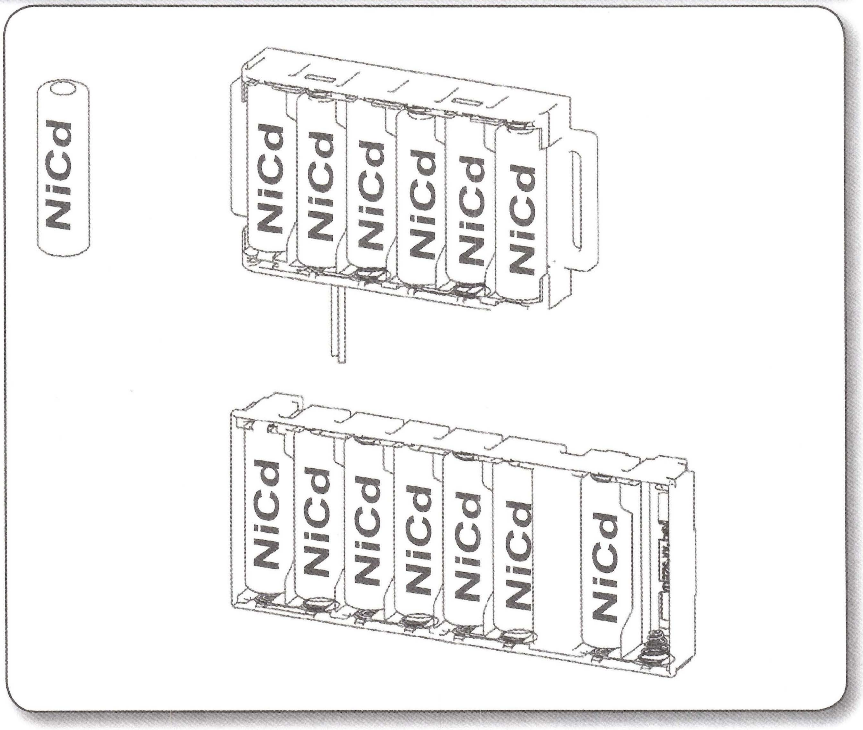
NiCd Rechargeable AA batteries

NiCd (Nickel-Cadmium chemical composition) AA batteries are recommended for use in the Vex Robotics Design System. Modern NiCd batteries do not suffer from any sort of permanent memory effect.

You will need to purchase six AA batteries for the Micro Controller and eight AA batteries for the Transmitter (14 batteries total). You will also need to purchase an NiCd battery recharger (be sure to get one that specifically) charges NiCd batteries).

For battery installation instructions, see the beginning of this chapter.

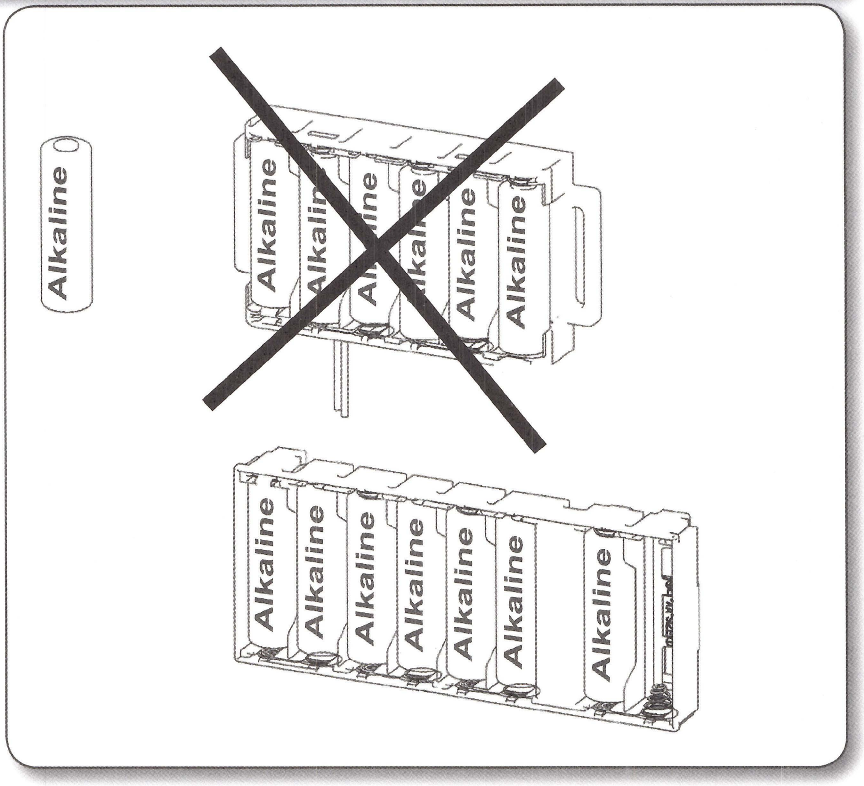
Note: Disposing of NiCd rechargeable batteries in the trash is illegal in many countries and states.



Important: The EPA certified RBRC® Battery Recycling Seal on the nickel-cadmium (NiCd) battery indicates Innovation One voluntarily participates in an industry program to collect and recycle these batteries at the end of their useful life, when taken out of service in the United States or Canada. The RBRC program provides a convenient alternative to placing used NiCd batteries into the trash or the municipal waste stream, which may be illegal in your area. Please call 1-800-8-BATTERY for information on NiCd battery recycling and disposal bans/restrictions in your area. Innovation One's involvement in this program is part of the company's commitment to preserving our environment and conserving our natural resources.

Battery Types, continued

Alkaline Rechargeble and Non-rechargeable AA batteries


Alkaline
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Alkaline

Alkaline batteries are NOT RECOMMENDED for the Vex Robotics Design System, but can be used in the transmitter.

Alkaline technology was not designed to handle the high levels of current that a robot requires (i.e. they cannot provide power fast enough), so the robot may lose power and turn off at unpredictable times. Alkaline batteries also provide a decreasing voltage as they are used up, so the level of power available to the robot falls as the batteries are drained.

NiCd batteries maintain their voltages reliably until they are almost completely empty. Finally, alkaline batteries, even "rechargeable" ones, are not truly rechargeable (rechargeable alkalines lose power with every recharge, and need to be replaced frequently). This means that their replacement cost will become prohibitive over time.

This includes the newer alkaline batteries that claim to be "designed for use in high tech devices," but still suffer from the same drawbacks which make all alkaline batteries impractical for robot use.

concepts to understand, continued

Battery Care

First Use

If you are using rechargeable batteries (and you should be!), remember to let them charge fully the first time before you use them because they are usually shipped uncharged. Be sure to let them reach full capacity in order to ensure a healthy battery charging cycle.

Memory Effect and Voltage Drop

A myth that often surfaces about rechargeable batteries is the "memory effect". This refers to a mistaken belief that total battery capacity diminishes permanently by a failure to drain the battery to zero voltage and then recharge it to full. "Memory effect" does not exist in consumer devices, only in very specific laboratory conditions.

A real phenomenon called "voltage drop" does exist that can easily be mistaken for the fictitious "memory effect." Voltage drop is a measurable phenomenon where a battery that is repeatedly "shallow discharged" (used only part way before recharging) will start delivering lower and lower voltages, and will run out sooner.

Discharge Cycles

The good news about voltage drop is that it is not permanent, and it is curable. If your batteries seem to be getting shorter life than usual, all you need to do is run them down until the Vex Robot Micro Controller automatically turns off, or the transmitter displays its low voltage warning (this will happen between 1 and 1.1V per cell—6.5V for the robot, 8.5V for the transmitter), then charge them back to full again. You may need to perform the drain/recharge process a few times, but your batteries should steadily improve in performance each time until they are back to full strength.

Never discharge a NiCd cell to less than .9-1.0V. By not discharging the batteries farther than this (known as "deep cycling"), you will avoid a condition that could potentially damage your batteries and/or charger.

concepts to understand, continued

Battery Care, continued

Overcharge/Trickle Charge

In addition to not excessively draining rechargeable batteries, you should also avoid overcharging them. Overcharging can cause permanent damage to the battery. It is important that you get a good NiCd charger that knows when to stop adding charge to the batteries. Once the battery has reached full charge, the charger should switch over into "trickle charge" mode, which is a low current mode that can be safely applied over a long period of time to maintain a full charge, or shut off the charger.

Temperature

Charging or draining batteries quickly will result in them heating up. Excessive heat can also cause permanent damage to the battery, and should be avoided. Also do not store batteries in high temperature conditions. If batteries are hot after charging or running, let them cool down before charging or running.

Age

Rechargeable NiCd batteries can be used over and over again for hundreds of battery cycles if properly maintained. However, all batteries will eventually wear out over time, and you should keep in mind that if you notice an old set of batteries is not performing as well as it used to, it may be time to get a fresh set.

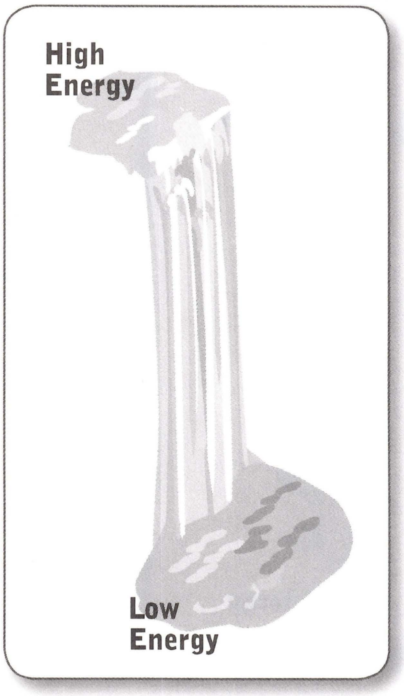
Environmental Issues

The cadmium found in NiCd batteries is highly toxic, and should not be disposed of in the trash. It is illegal to do so in many countries and states. Check your local regulations for information on proper battery recycling procedures in your area.

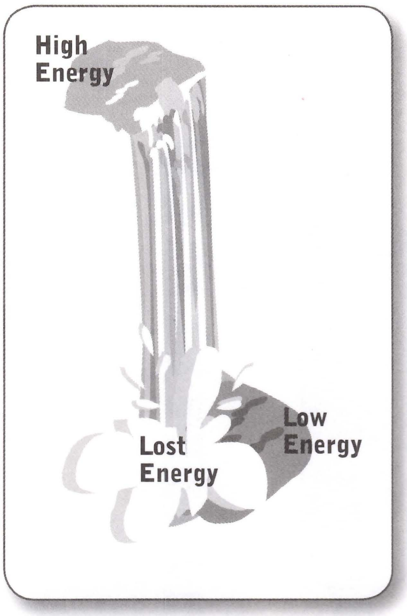
concepts to understand, continued

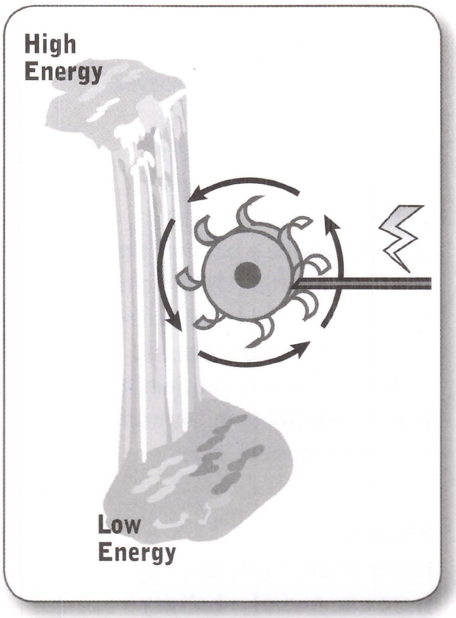
Voltage and Energy

Any time something in the physical world has the potential to go from one location to another there is an opportunity for it to do some useful work along the way. When water runs over a cliff, it falls downward because gravity is pulling on it. A hydroelectric generator takes advantage of this by having the water turn a turbine along the way as it falls



When the water was up on top of the cliff, it had a lot of "gravitational potential energy", energy that was stored in the water because it was high up even though gravity wanted to pull it downwards. After falling to the bottom of the cliff, it got rid of some of its gravitational potential energy. Normally, the energy that was given up by the water is wasted (it gets transformed into other forms of energy, like sound and heat as the water hits the bottom), but if the water runs through a hydroelectric generator, the generator instead takes the energy and transforms it into a form that is useful to us, as electrical energy.





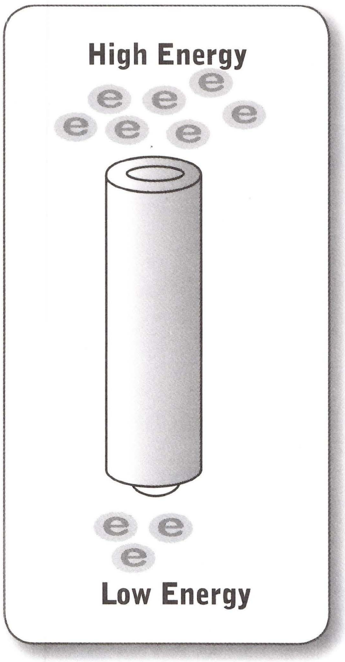
concepts to understand, continued

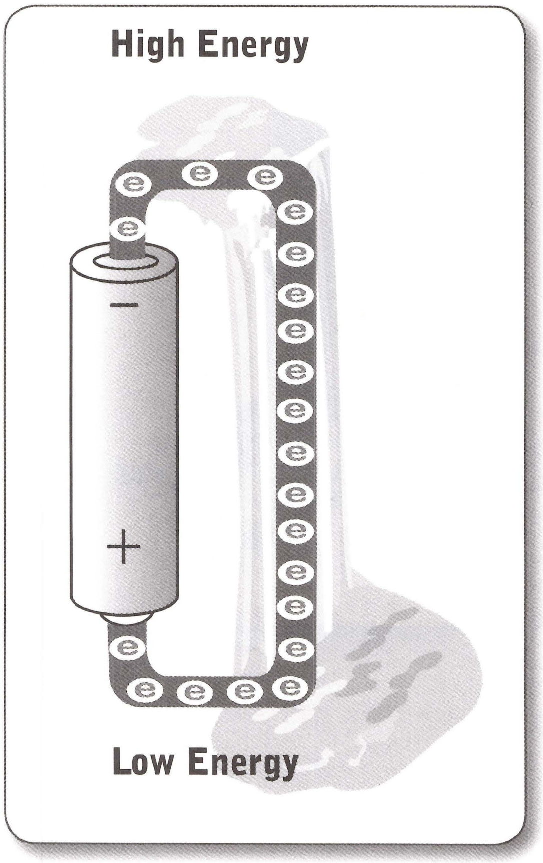
Voltage and Energy, continued

Electrons have negative charges, and naturally move toward areas with positive charges because opposite charges attract. A battery is like the cliff. One end (the – side) holds electrons at an area where they have high potential energy, just like the top of the cliff. The other side (the + end) is like the bottom of the cliff, an area of low potential energy that the electrons would like to travel toward. "Voltage" is the term used to describe the difference in electrical potential energy between two regions, hence a 1.5V battery has 1.5 volts of difference between the region at the + end and the region at the – end.

Unlike the waterfall, however, the battery doesn't just let the electrons travel freely from the high-energy end to the low-energy end. You need to provide a path for the electrons in order to let them get from one end to the other by connecting the battery to a circuit. The wire provides a path for electrons to get from the – side to the + side.

Warning:
Never hook a wire directly from one end of a battery to the other as the battery will become extremely hot.



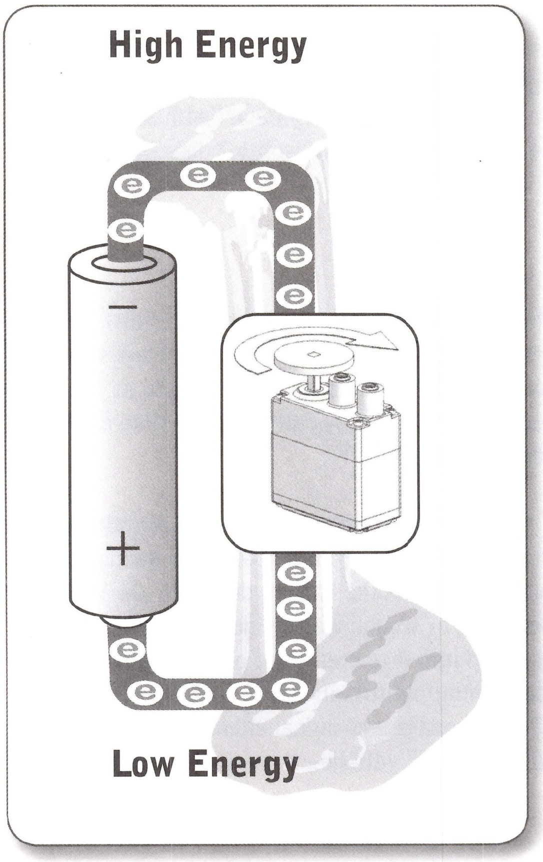


concepts to understand, continued

Voltage and Energy, continued

The last step in the process is to add the hydroelectric generator. Except instead of a generator, you will be harvesting the energy from the moving electrons, with motors that change the electrical energy into physical energy and computer chips that use the energy to power other circuits inside them.

This is, of course, a huge simplification of the way electricity really works in a circuit, but the ideas behind voltage should still be clear: that there are regions with different amounts of potential energy, that the battery is what maintains that difference, and that the rest of the electronic components in the robot are effectively drawing their power from the electrons that are trying to move from one region to the other.



concepts to understand, continued

Voltage and Energy, continued

Batteries in Series

Batteries can be stacked together in series to add their voltages together, like stacking cliffs to make a bigger cliff. This is how multiple AA batteries (which are 1.2-1.5V each) produce a single larger "battery pack" with a combined voltage of around 7.2V in the Vex system. The Transmitter does the same thing to achieve a voltage of 9.6V.

Battery Cells

Individual batteries (like a single AA) are often called "cells," to distinguish them from the entire "battery" pack. Technically, a "battery" refers strictly to a collection of multiple cells, so what we have been referring to as a battery pack is a "battery", and what we usually call a battery (like an AA battery) is technically not a battery, but a "cell".

The word "cell" comes from the nature of the battery as a self-contained vessel for the chemical reaction necessary to produce a specific electrical voltage. The name comes from an early 1800's battery design by Dr. William Cruickshank, in which a wooden box or trough was divided into "cells," and each cell had a metal plate inserted into it to create the electrochemical reaction. A modern battery pack (multiple AAs in series, for instance), similarly, has multiple "cells" with separate chemical chambers, which work together to produce the overall "battery" voltage.

subsystem interactions

How does the Power Subsystem interact with...

...the Structure Subsystem?

- The structure subsystem generally provides a safe, protected place to secure the battery.
- On the Squarebot, the structure subsystem provides a mounting platform for the batter holder, on the underside of the chassis (see Power Subsystem building instructions).

...the Motion Subsystem?

- The Motion Subsystem's motors and servomotors convert electrical energy into physical energy, and so they will of course need electrical energy to work with. This energy is ultimately supplie by the Power Subsystem's batteries, but the motors do not plug into the batteries directly. Rather, the flow of power is directed by the Micro Controller, which decides how much power is allowed to flow from the Power Subsystem to the Motion components.

...the Sensor Subsystem?

- Sensors, like all electronic components, require power in order to function. Vex sensors draw power indirectly from the Power Subsystem through the Micro Controller (Logic Subsystem).

...the Control Subsystem?

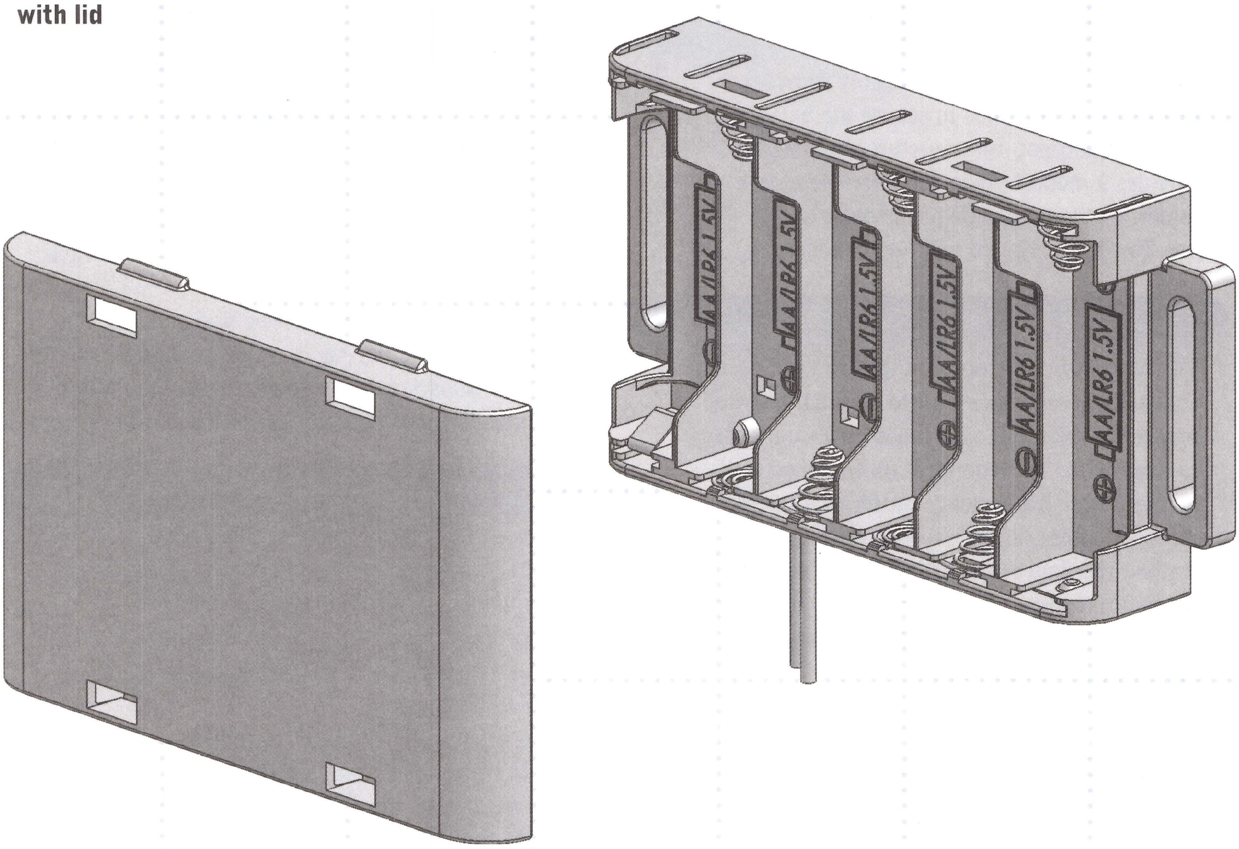
- Broadcasting radio waves takes a significant amount of electrical power. The eight AA batteries (or 9.6V battery pack) installed in the Vex Transmitter provide the Transmitter with all the power it needs to operate its internal circuitry and send out radio waves carrying commands to the receiver.
- The RF Receiver module mounted onboard the robot, on the other hand, draws its power from the Power Subsystem indirectly, through the Micro Controller (which is part of the Logic Subsystem).

... the Logic Subsystem?

- Since the Micro Controller is a device that contains a large number of electronic components, including two computer microprocessors, it needs power, which it draws directly from its connection to the Power Subsystem.
- The other major function of the Micro Controller is to control the other subsystems on the robot. It does this by selectively routing powe from the Power Subsystem batteries to the other subsystems' components (like motors).
- The Power Subsystem battery holder (or battery pack) connects to the Micro Controller module using a two-pin connector inside a plastic housing, which is mechanically "keyed" to prevent it from being plugged in backward.

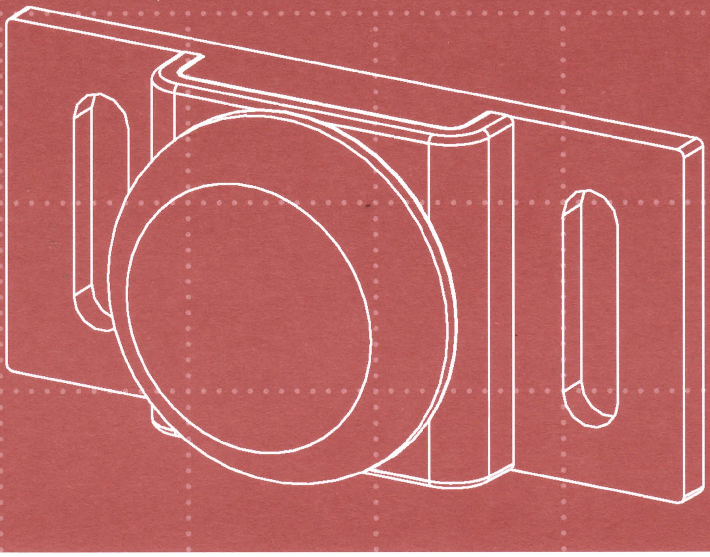
power subsystem inventory

component	qty
battery holder with lid	1


AA/LR6 1.5V
AA/LR6 1.5V
AA/LR6 1.5V
AA/LR6 1.5V
AA/LR6 1.5V
AA/LR6 1.5V

sensors

The sensor subsystem gives the robot the ability to detect various things in its environment. The sensors are the "eyes and ears" of the robot, and can even enable the robot to function independently of human control.



sensor

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squarebot sensor subsystem parts & assembly 5.3

concepts to understand 5.5

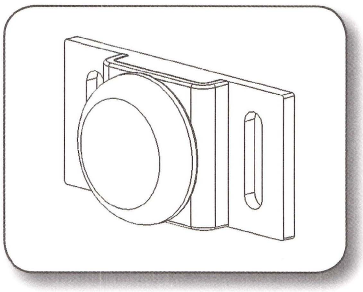
subsystems interfaces 5.13

structure subsystem inventory 5.14

the purpose of sensors

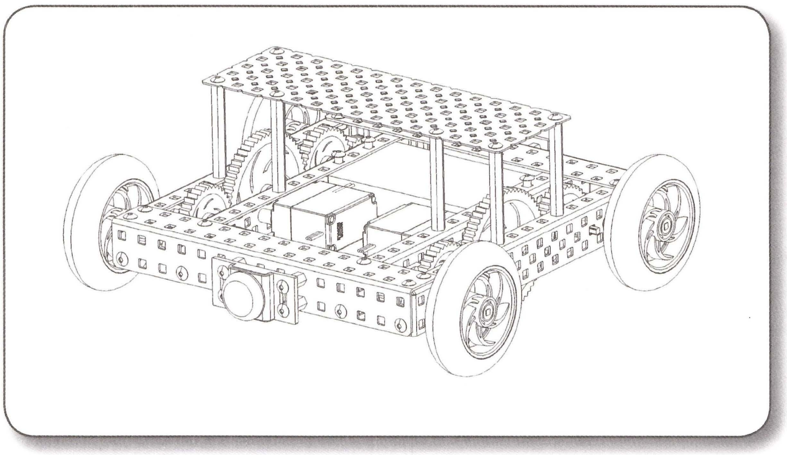
A robot is more than just a radio-controlled vehicle with extra parts. Both a radio-controlled car and a robot can move around using onboard power and motors, and both can be controlled via radio waves. The robot, however, has two critical capabilities that the simple R/C car does not: the robot can sense its environment, and the robot can adjust its own behaviors based on that knowledge.

Sensors are the beginning of that process. A sensor will generally tell the robot about one very simple thing in the environment, and the robot's program will interpret that information to determine how it should react.



The Bumper Switch sensor, for instance, will tell the robot whether it is in contact with a physical object or not. Depending on how the sensor is set up, this can tell the robot a lot of different things. If the sensor is mounted on the front bumper, the robot could use this information to tell whether it has run into a wall inside a maze. In a game of tag, the bumper can function as the robot's "tag point," where a push on the sensor would indicate that the robot has been tagged.

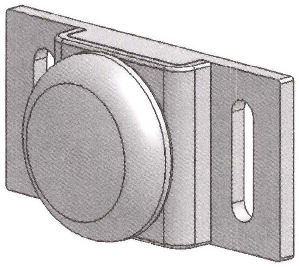
By making good use of sensors to detect the important aspects of its environment, a robot can make things much easier for its human operator, or even operate completely independent of human control.



squarebot sensor subsystem parts & assembly

1 Find the bumper switch sensor

bumper switch sensor x 2



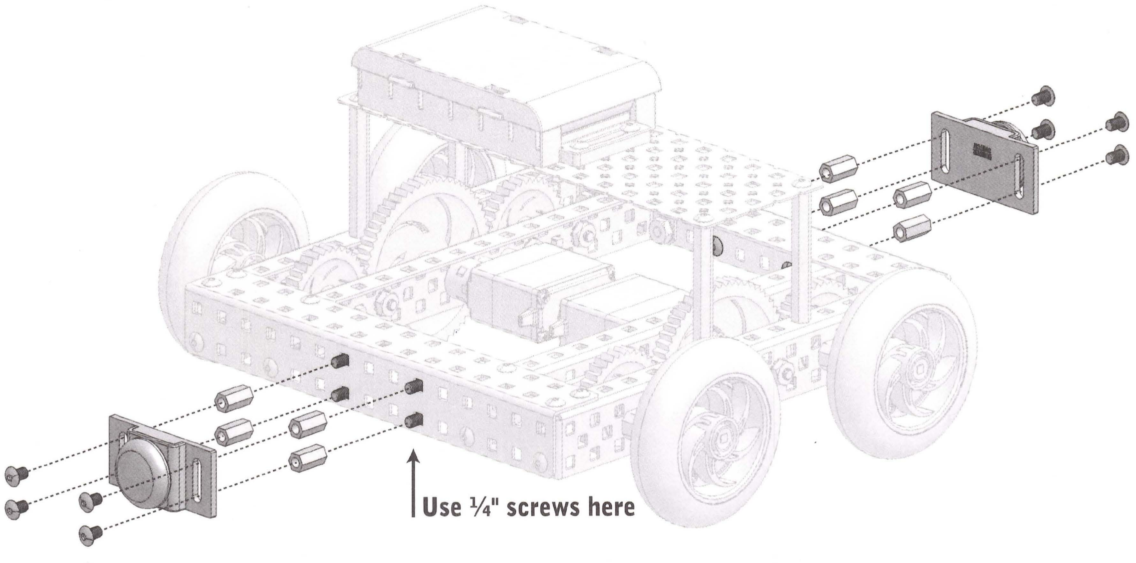
8-32 hex screw, ¼" x 8

8-32 hex screw, ⅜" x 8

Fully threaded beam, ½" x 8

2 Attach the bumper switch sensor

Attach one bumper sensor to the front of the robot, and one bumper sensor to the rear of the robot. Start by positioning four ¼" screws in the front chassis rail of the robot as shown, and twisting a ½" fully threaded beam onto each one. Attach the sensors facing outwards with four ⅜" screws. The screws should go through the mounting holes in the sensor, and screw into the threaded beams on the other side.



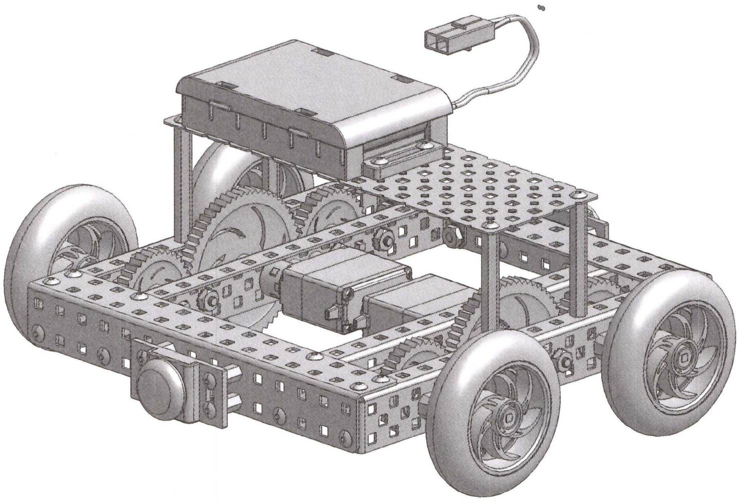
Use ¼" screws here

Use ⅜" screws here

squarebot sensor subsystem parts and assembly, continued

2 Attach the bumper switch sensor, continued

Check your assembly. It should look like this.

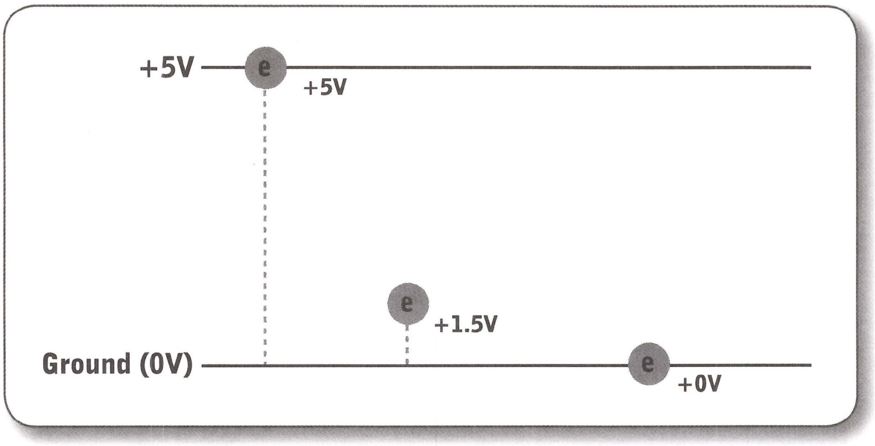


concepts to understand

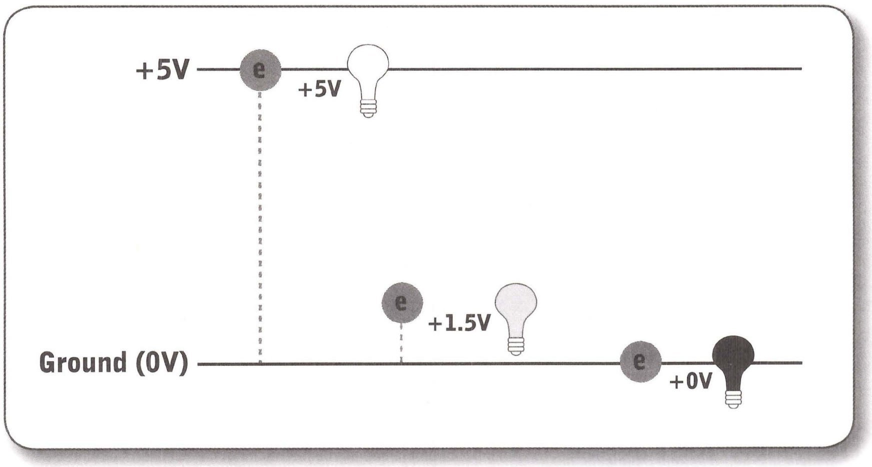
Analog vs. Digital

Among sensors, there are two main electrical "languages" spoken: Analog and Digital.

Analog sensors communicate with the micro controller by sending it an electrical voltage along a wire. By measuring where the sent voltage falls between zero and maximum voltage, the micro controller can interpret the voltage as a numeric value for processing. Analog sensors can therefore detect and communicate any value in a range of numbers.



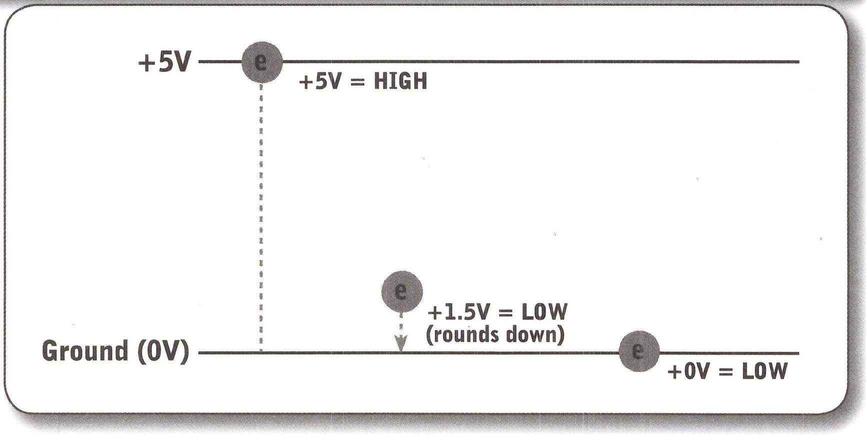
A light sensor, for instance, can communicate how bright a light is by sending a zero voltage for total darkness, sending maximum voltage for a very bright light, or sending an in-between voltage for any other amount of light, depending on exactly how bright it is.



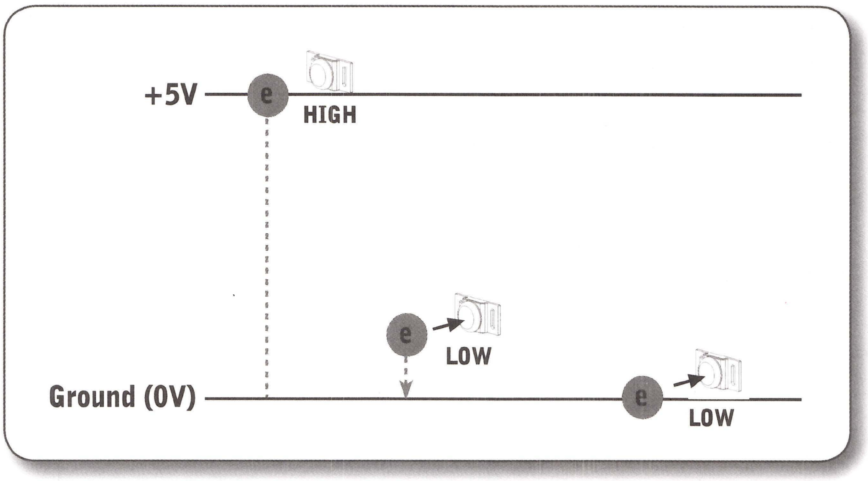
concepts to understand, continued

Analog vs. Digital, continued

A weakness of analog sensors is that it is very difficult to send and maintain an exact, specific voltage on a wire in a live circuit. Digital sensors, on the other hand, can send signals very reliably, even in electrically "noisy" conditions. However, they do so by sacrificing the ability to indicate the entire range of values. Digital signals can only have one of two values: either HIGH or LOW.



A digital sensor sends a voltage, just like an analog sensor, but instead of sending a voltage between zero and maximum, it will send only zero OR maximum. If the micro controller detects a voltage that is between the two, it assumes that the difference is caused by electrical noise, and rounds the voltage either up to maximum, or down to zero, whichever is closer.

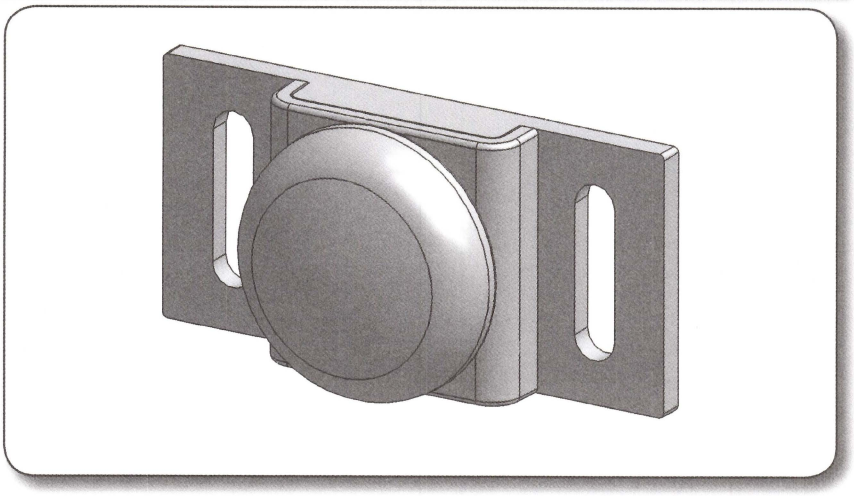


It may seem like a terrible loss to only be able to indicate two values rather than a whole range, but in many situations, this is preferable. For instance, the Bumper Switch Sensor included in the Starter Kit is a digital sensor. Since the purpose of the sensor is to detect whether something is pushing the bumper in or not, two values are all it needs to do its job.

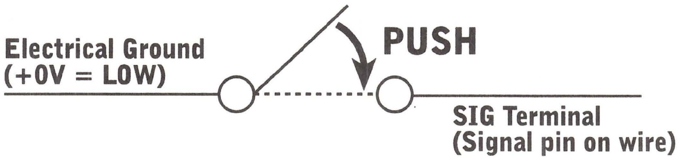
concepts to understand, continued

Bumper Switch Sensor

Bumper Switch Sensor
Signal: Digital
Description: The bumper sensor is a physical switch. It tells the robot whether the bumper on the front of the sensor is being pushed in or not.

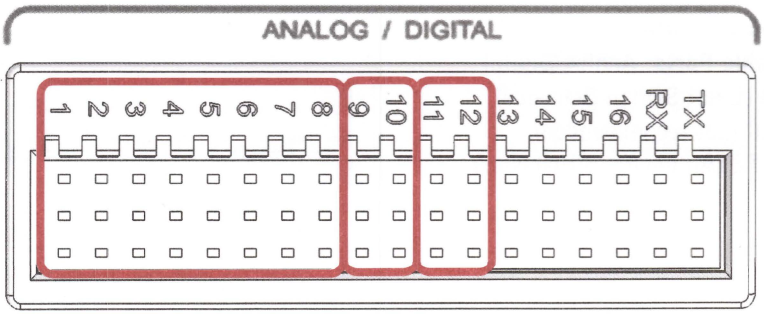


Technical Info:
Type: SPST switch ("Single Pole, Single Throw") Normally Open
Signal Behavior: When the switch is not being pushed in, the sensor maintains a digital HIGH signal on its sensor port. When an external force (like a collision or being pressed up against a wall) pushes the switch in, it changes its signal to a digital LOW until the switch is released.


Electrical Ground
(+0V = LOW)
PUSH
SIG Terminal
(Signal pin on wire)

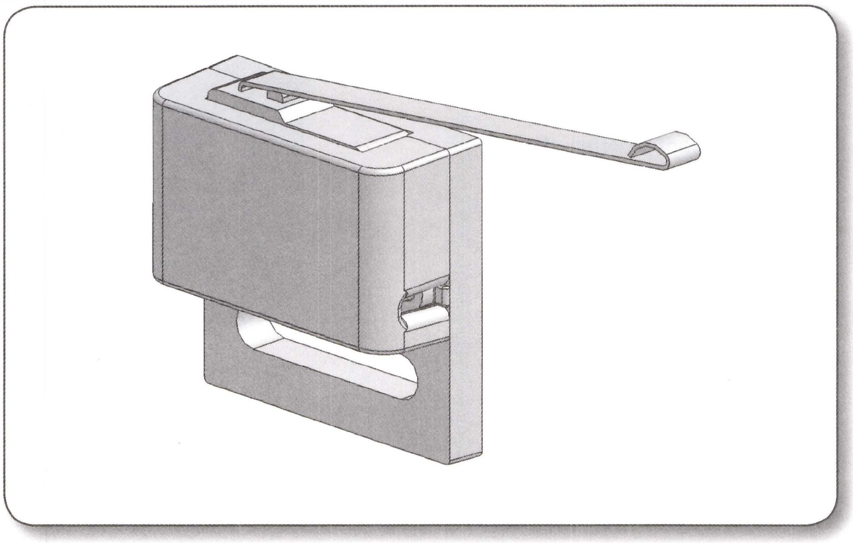
Signal pin is HIGH when switch is open
Pushing switch brings the signal pin voltage to LOW

Behavior Info:
Usable Ports: Analog/Digital 1-8 (Limit Switch Behavior), 9-10 (Tag Behavior), 11-12 (Autonomous Behavior)

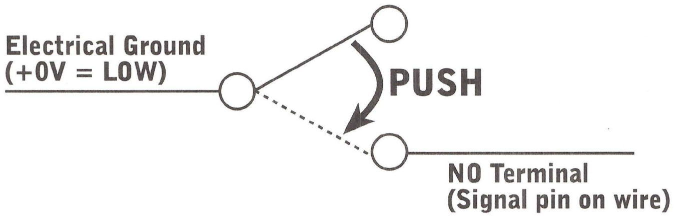

ANALOG / DIGITAL
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
RX
TX

Limit Switch Sensor

Limit Switch Sensor
Signal: Digital
Description: The limit switch is a physical switch. It can tell the robot whether the sensor's metal arm is being pushed down or not.

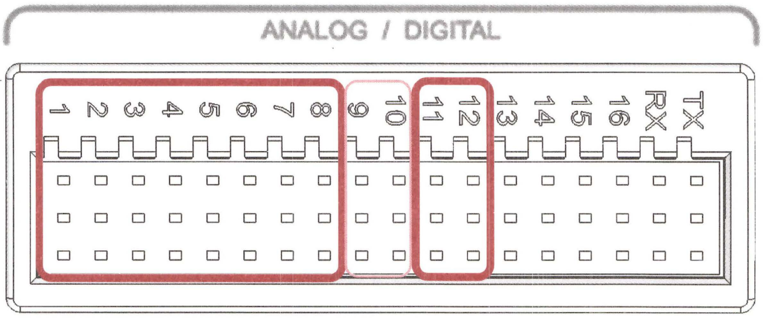


Technical Info:
Type: Modified SPDT microswitch, configured for SPST Normally Open behavior
Behavior: When the limit switch is not being pushed in, the sensor maintains a digital HIGH signal on its sensor port. When an external force (like a collision or being pressed up against a wall) pushes the switch in, it changes its signal to a digital LOW until the limit switch is released.


Electrical Ground
(+0V = LOW)
PUSH
NO Terminal
(Signal pin on wire)

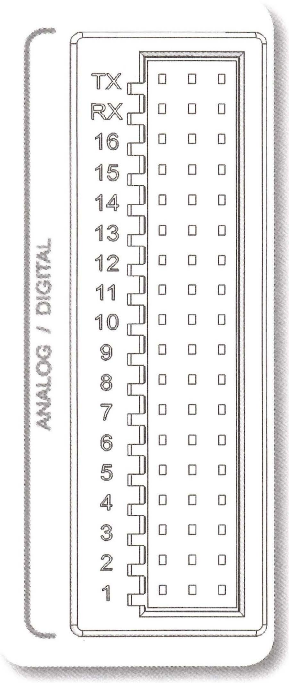
Pushing switch brings the signal pin voltage to LOW

Behavior Info:
Usable Ports: Analog/Digital 1-8 (Limit Switch Behavior), 9-10 (not recommended), 11-12 (Autonomous Behavior)


ANALOG / DIGITAL
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
RX
TX

Starter Kit Sensors—Programmed Behaviors

All sensors connect to the Analog/Digital port bank on the Vex Micro Controller. Different behaviors will be activated depending on which port you plug the sensors into. The following behaviors are activated when Bumper Switch or Limit Switch Sensors are plugged into the indicated ports. More detailed information about each behavior can be found on the next few pages.



Jumper Ports

Port	Function
Analog/Digital Port 13	Enables Autonomous Mode

Sensor Ports

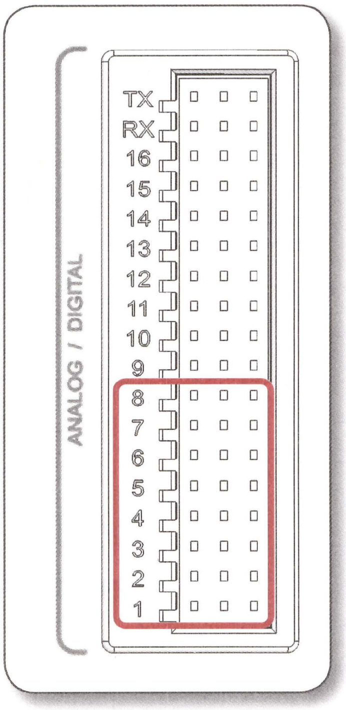
Port	Category	Behavior
Analog/Digital Port 12	Autonomous Mode Collision Detection Ports	Back up and turn left
Analog/Digital Port 11		Back up and turn right
Analog/Digital Port 10	Tag or Collision Emergency Stop Ports	Stop for 2 seconds
Analog/Digital Port 9		Stop for 2 seconds
Analog/Digital Port 8	Limit Switch Behavior	Motor 7 ignores CW
Analog/Digital Port 7		Motor 7 ignores CCW
Analog/Digital Port 6		Motor 6 ignores CW
Analog/Digital Port 5		Motor 6 ignores CCW
Analog/Digital Port 4		Motor 5 ignores CW
Analog/Digital Port 3		Motor 5 ignores CCW
Analog/Digital Port 2		Motor 4 ignores CW
Analog/Digital Port 1		Motor 4 ignores CCW

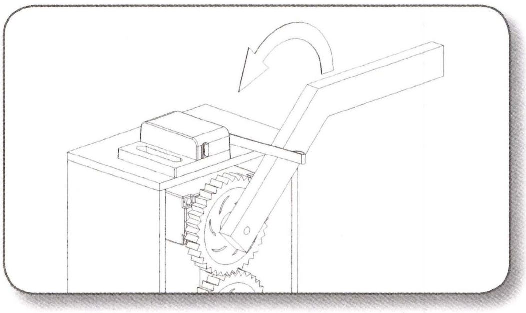
CW = Clockwise
CCW = Counter Clockwise

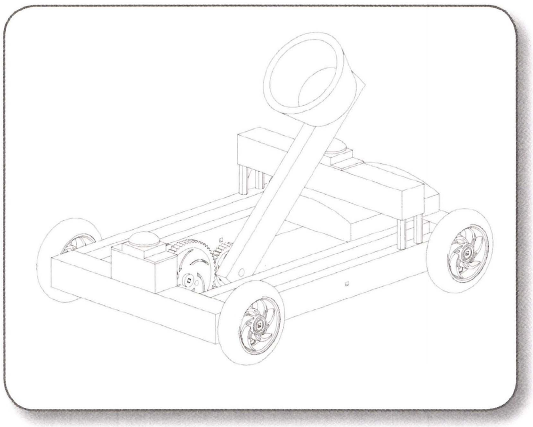
Other Ports
Ports 14-16, RX, and TX are not used by sensors.

Starter Kit Sensors—Programmed Behaviors

Limit Switch Primary Behavior: Mechanical Limit Switch (Ports 1-8)
Bumper Switch Secondary Behavior: High Durability Limit Switch (Ports 1-8)





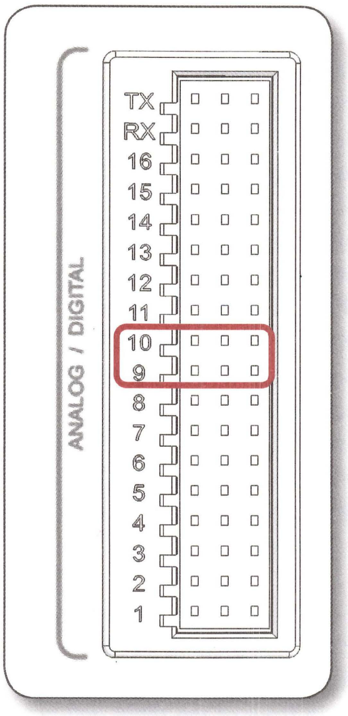


Mechanical/High Durability Limit Switch

- Plug the Bumper or Limit Switch Sensor into a port from 1 to 8 to use this behavior. You may use more than one port if desired (one sensor per port), but they do not do exactly the same thing.
- When pressed, a switch on ports 1-8 will limit the motion of one of the motor ports:
  - Analog/Digital Port 1 pressed: Motor port 4 will ignore commands to run Counterclockwise
  - Analog/Digital Port 2 pressed: Motor port 4 will ignore commands to run Clockwise
  - Analog/Digital Port 3 pressed: Motor port 5 will ignore commands to run Counterclockwise
  - Analog/Digital Port 4 pressed: Motor port 5 will ignore commands to run Clockwise
  - Analog/Digital Port 5 pressed: Motor port 6 will ignore commands to run Counterclockwise
  - Analog/Digital Port 6 pressed: Motor port 6 will ignore commands to run Clockwise
  - Analog/Digital Port 7 pressed: Motor port 7 will ignore commands to run Counterclockwise
  - Analog/Digital Port 8 pressed: Motor port 7 will ignore commands to run Clockwise
- This behavior is used to limit the motion of a motor in order to make sure that it does not turn too far (for instance, a gripper claw does not attempt to open too wide). The sensor is placed at the outer limit of desired movement, so that any attempt to move farther will trigger the sensor.
- Use a Bumper Switch for this behavior only if a standard limit switch sensor will not work (for example, because the expected impact is too strong for the limit switch). A normal limit switch is better than the bumper switch in most situations because the bumper switch is less precise (due to the bumper's more rugged construction).
- Suggested use: Motion-limiting switch for custom attachments and other moving parts.

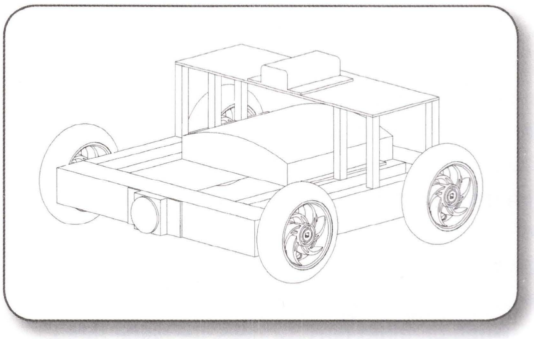
Starter Kit Sensors—Programmed Behaviors

Bumper Switch Primary Behavior: Tag/Emergency Stop Sensor (Ports 9-10)



Tag/Emergency Stop Sensor

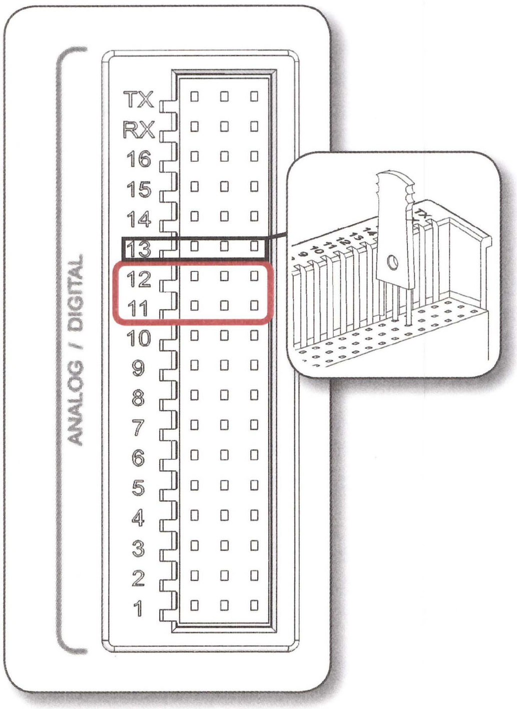
- Plug the Bumper Switch Sensor into Port 9 or 10 to use this behavior. You may use both ports if desired (one sensor per port, they do the same thing).
- When the bumper sensor on one of these ports is pressed in, the robot will come to a halt and operator control will be disabled for 2 seconds. To create a visual indicator that the bumper was triggered and the motor ports were disabled, attach a motor or servomotor to Motor Port 6. This motor will oscillate back and forth for 2 seconds when the bumper is hit.
- When control is returned, the sensor will not trigger for another 2-3 seconds in order to allow the operator to move away from the hazard or the other robot.
- This behavior is not recommended for use with the Limit Switch Sensor due to durability considerations.
- Suggested uses: Collision detection, Tag game sensor

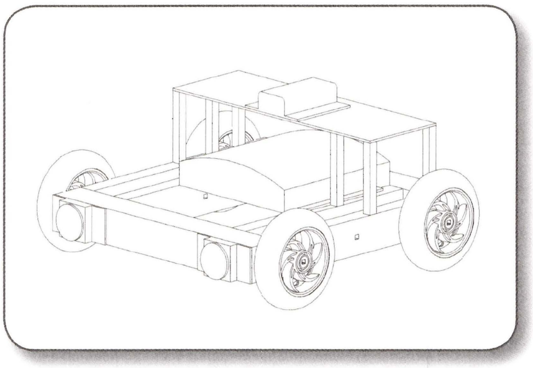


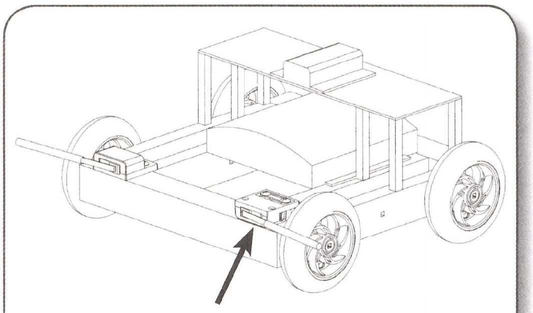
concepts to understand, continued

Starter Kit Sensors—Programmed Behaviors

Autonomous Behavior: Autonomous Mode Obstacle Detector (Ports 11-12 + Jumper 13)






In order to mount the left limit switch, position it upside down using spacers to support the area where the screws are applied.

Autonomous Mode Obstacle Detector

- You must enable Autonomous Mode in order for these ports to work. Place a Jumper Clip on Analog/Digital Port 13 to enable Autonomous Mode operation.
- The robot should be set up in a 2-motor configuration for autonomous mode operation. The left motor should be plugged into Motor Port 3, and the right motor should be plugged into Motor Port 2. Both motors should use a two-gear configuration (like Squarebot) between the motor and each wheel.
- Plug Bumper or Limit Switch Sensors into Ports 11 and 12 to use this behavior. You should use both ports (one sensor per port), because they perform different functions, both of which are needed for optimal performance.
- If using Limit Switches, do not place them directly on the front of the robot, or you risk damage to the sensors. Attach semi-flexible "antenna" pieces to the limit switches to hang out in front of the robot and act as "feelers" that can trigger the sensitive limit switch without letting anything hit the switch itself. The picture in the bottom left shows the sensors with straws used as antenna pieces.
- The robot will drive straight forward without human control when in Autonomous Mode. When the bumper switch on input port 11 is pushed in, the robot will interpret this as an indication that it has run into an immovable obstacle on the left side, and will turn to the right until the switch is no longer pushed in. The bumper switch on input port 12 does the same thing, but monitors the right side and makes the robot turn left when it is pushed.
- Suggested use: Autonomous Mode Obstacle Detector

subsystem interactions

How does the Sensor Subsystem interact with...

...the Structure Subsystem?

- The structure subsystem provides a mounting and stabilization platform for sensors on the robot. Often, sensors need to be held in a specific position to function properly, and the structural subsystem must be designed to accommodate these needs.
- On the Squarebot, the structure subsystem provides a mounting spot for the bumper switch sensors, where they can detect collisions from the front and rear.

...the Motion Subsystem?

- Robots often have motors and other Motion components controlled by sensors (for instance, the emergency stop function stops the motors when the bumper switch sensor is pushed). However, the Sensor Subsystem does not directly control the Motion Subsystem. Instead, the Sensors provide information to the Micro Controller, which takes that information into account, and then decides what command to send to the Motion Subsystem.

...the Power Subsystem?

- Sensors, like all electronic components, require power in order to function. Vex sensors draw power indirectly from the Power Subsystem through the Micro Controller (Logic Subsystem).

...the Control Subsystem?

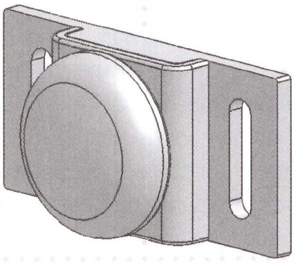
- The Control and Sensor Subsystems complement each other to achieve better control of the robot. The Control Subsystem provides human control over the robot, but the human operator does not always have perfect control, or the perfect point of view to see the robot's position. The Sensor Subsystem gives the robot the ability to make its own informed decisions, and can be a substantial aid to the human operator.
- On Squarebot, the bumper sensors function as both tag game sensors and as emergency stop triggers. In the event that the operator accidentally drives into a wall or other obstacle, the sensor will stop the robot for a few seconds to prevent motor damage that could occur if the operator attempts to continue running the motors when the robot is stuck.

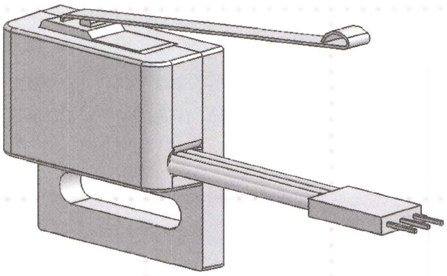
... the Logic Subsystem?

- The Logic Subsystem relies on feedback from the Sensor Subsystem to provide information about the robot's environment. It uses this data to make informed decisions about how the robot should behave.
- The actual behavior that is activated when a sensor is triggered depends on which port the sensor is plugged into on the Mico Controller.
- The Squarebot has two bumper sensors, one for the front and one for the rear. These will be plugged into the "Tag" behavior ports (in the Logic Subsystem chapter) to function in either the Tag game or as an emergency stop mechanism.

sensor subsystem inventory

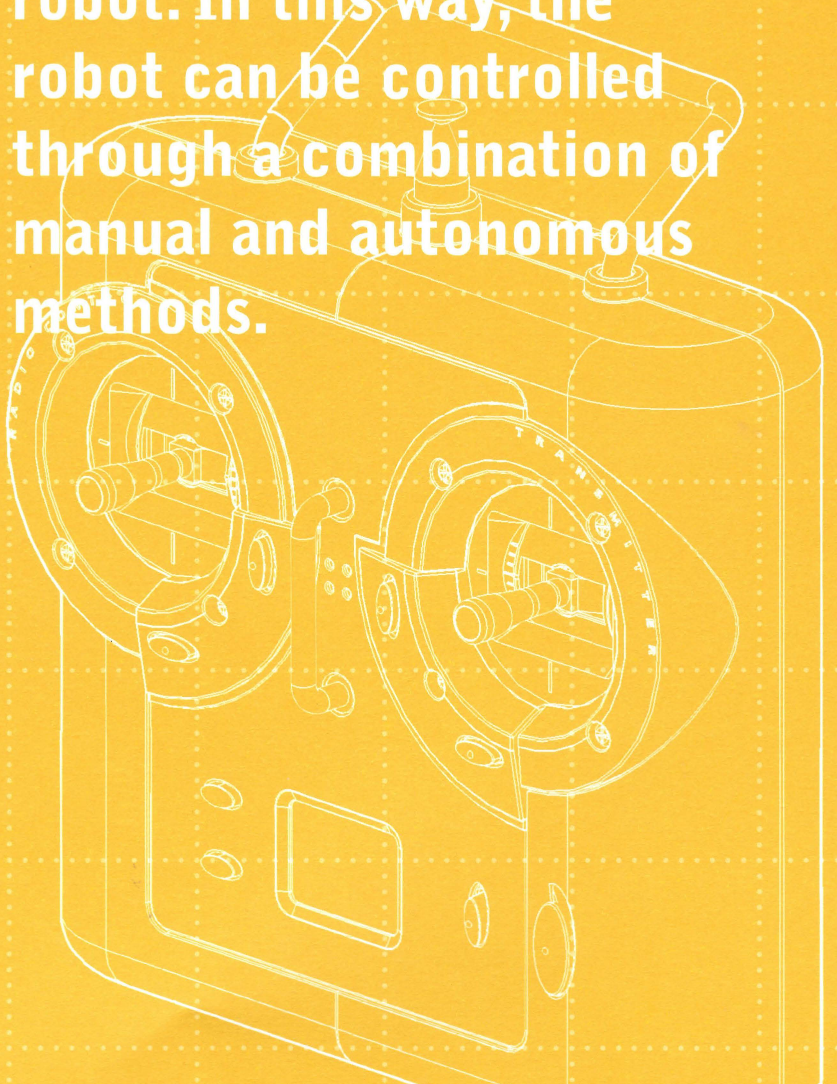
component	qty
bumper switch sensor	2
limit switch sensor	2





control

The Control Subsystem enables a human operator to maneuver the robot. Commands are issued through joysticks and buttons on the Transmitter, and sent via radio signal to the Receiver on the robot. In this way, the robot can be controlled through a combination of manual and autonomous methods.



control

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the purpose of the RF Receiver Module 6.2

squarebot RF Receiver Module parts & assembly 6.3

concepts to understand 6.7

subsystems interfaces 6.23

control subsystem inventory 6.24

squarebot control subsystem parts & assembly

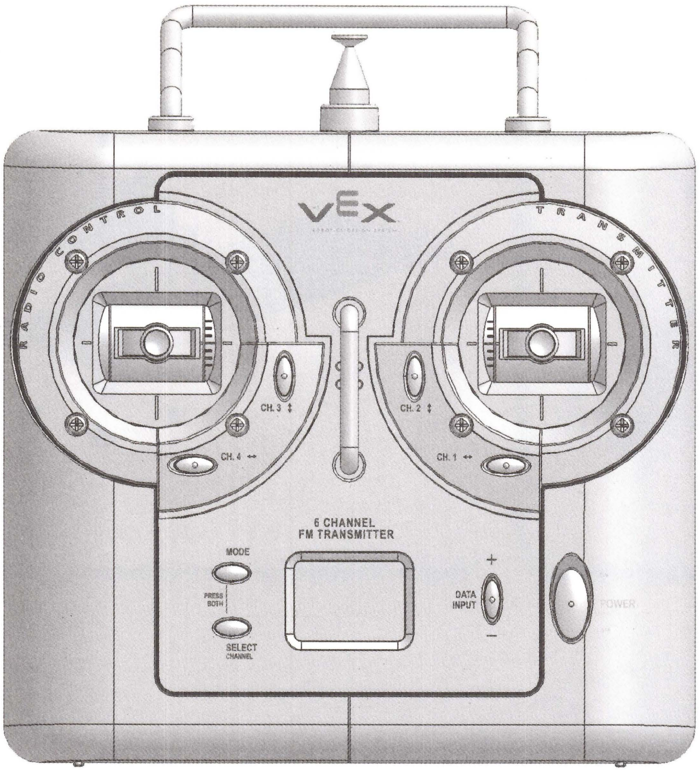
The control subsystem provides the link between the robot and the human operator. Commands are entered through the joysticks and buttons on the RF Transmitter, and sent through the air via FM radio waves to the RF Receiver module mounted on the robot.

1 **Collect and identify the parts from the list of materials below:**

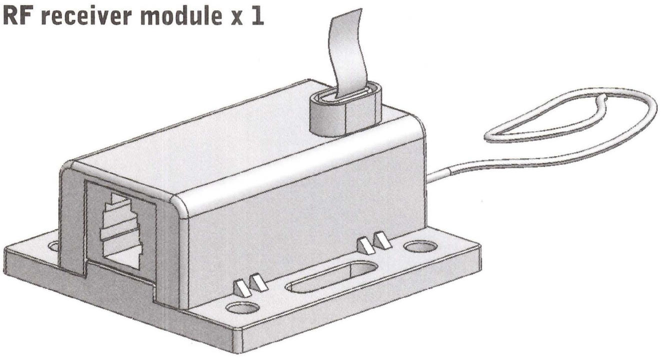
materials	qty
radio transmitter	1
transmitter antenna	1
RF receiver	1
receiver crystal (75MHz)	1
8-32 hex screw, 3/8"	5
keps nut	5
receiver antenna sleeve	1
receiver antenna sleeve holder	1

squarebot control subsystem parts & assembly, continued

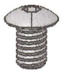
transmitter x 1


RADIO CONTROL
TRANSMITTER
VEX
CH. 3
CH. 2
CH. 4
CH. 1
6 CHANNEL
FM TRANSMITTER
MODE
PRESS BOTH
SELECT CHANNEL
DATA INPUT
+
−
POWER

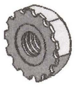
RF receiver module x 1



8-32 hex screw, $^3/_8$" x 5

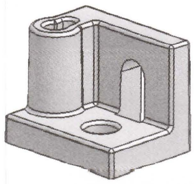


keps nut x 5



receiver antenna sleeve x 1

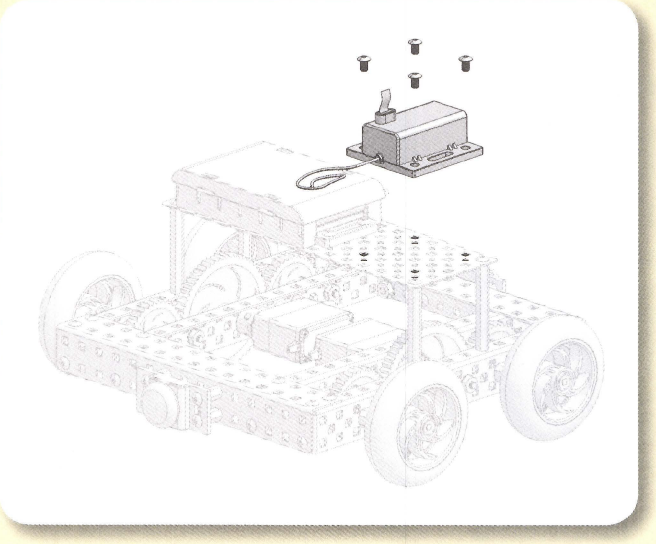
receiver antenna sleeve holder x 1

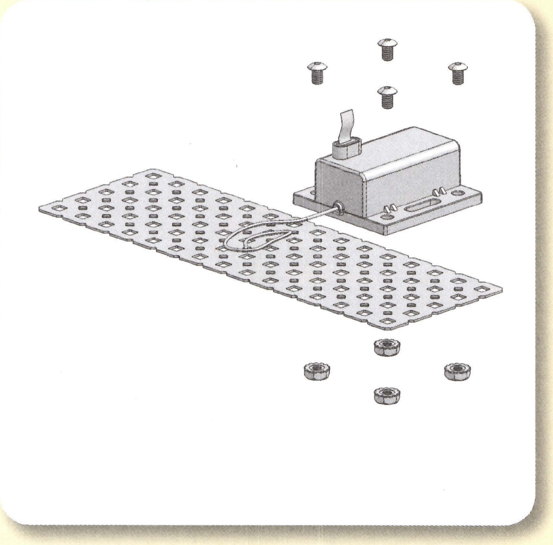


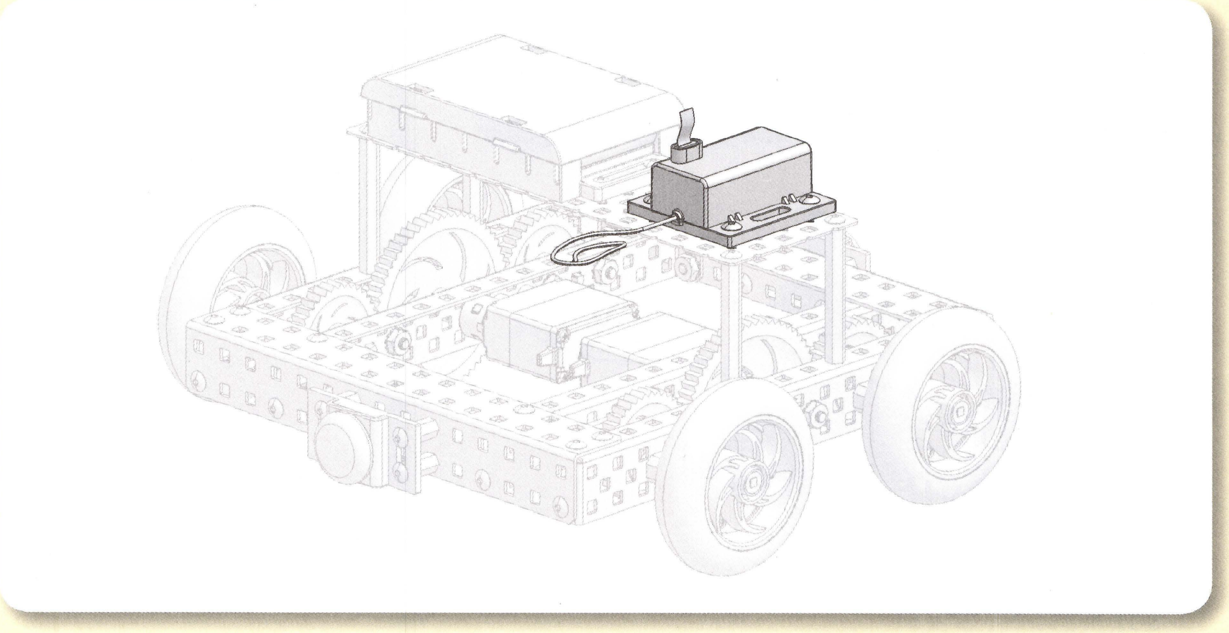
squarebot control subsystem parts & assembly, continued

2 Attach the RF Receiver Module to the robot:

Position the RF receiver module on top of the the Squarebot deck, and secure it with four 3/8" screws and keps nuts.

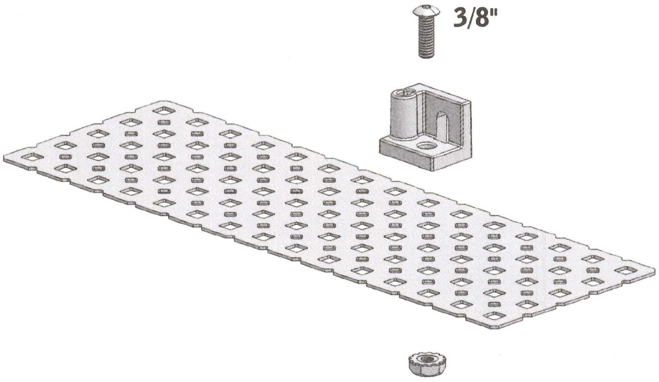


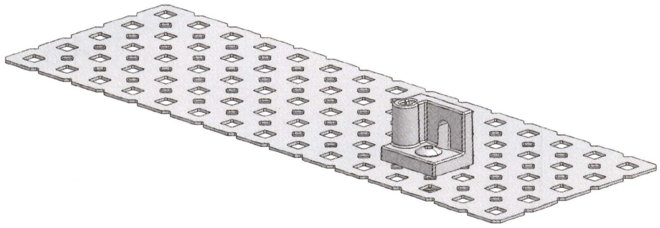


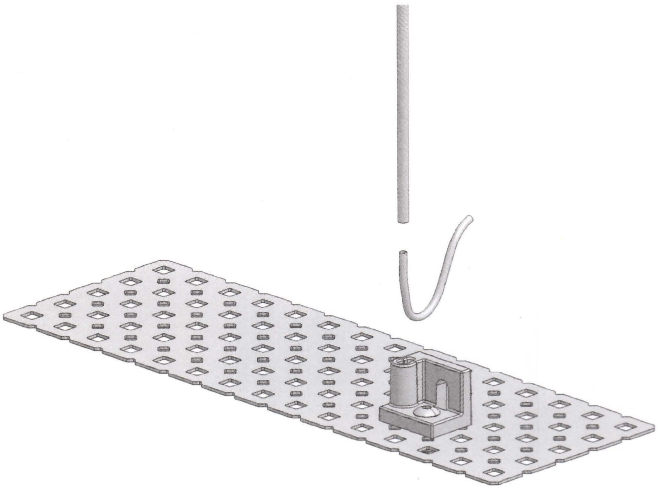


squarebot control subsystem parts & assembly, continued

3 Attach the Antenna Holder to the robot:

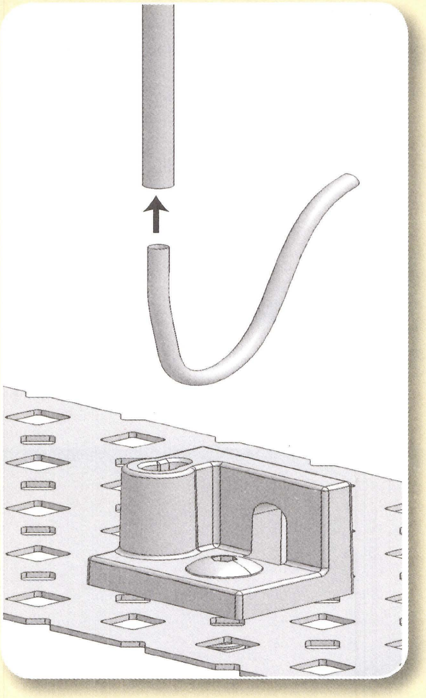


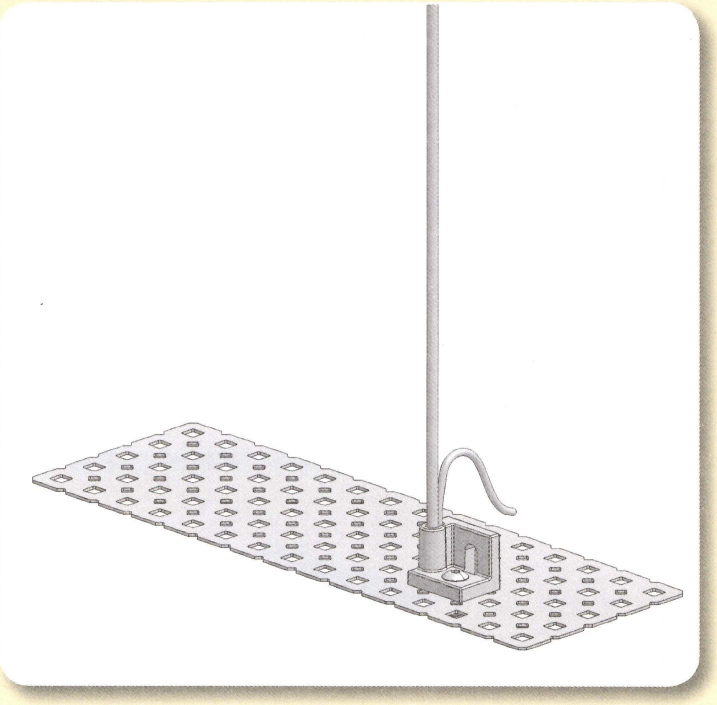


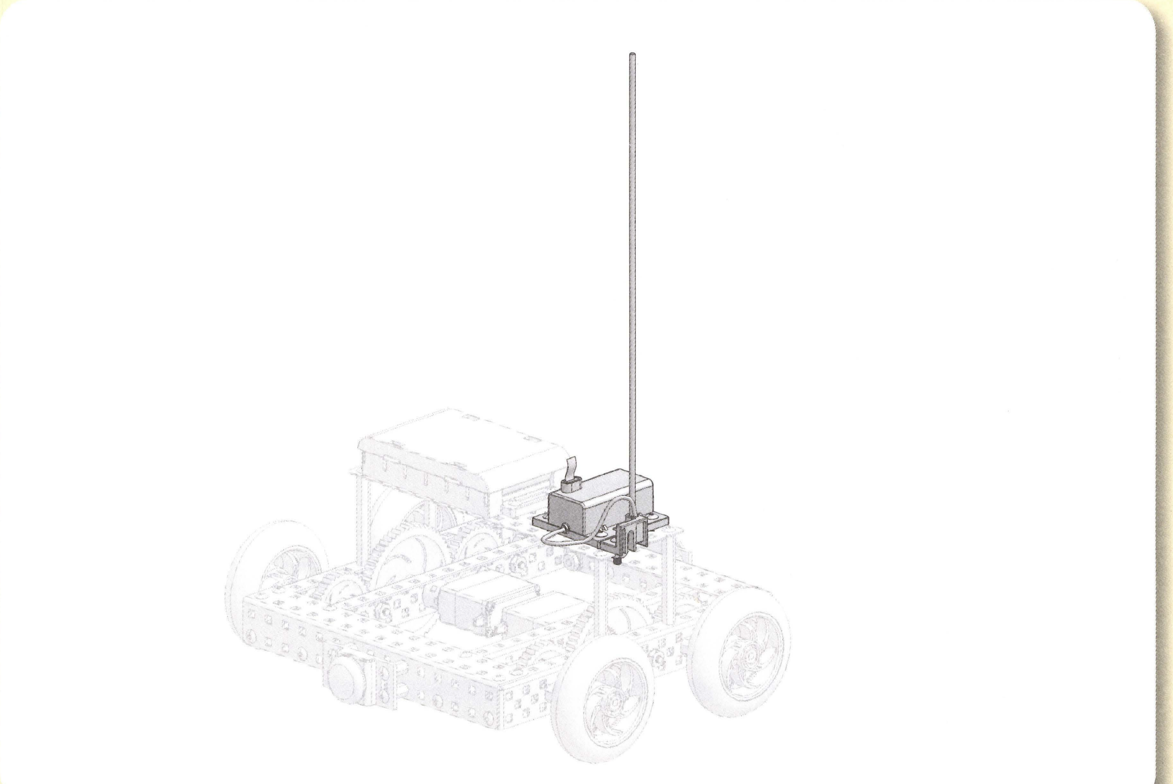


squarebot control subsystem parts & assembly, continued

3 Attach the Antenna Holder to the robot:





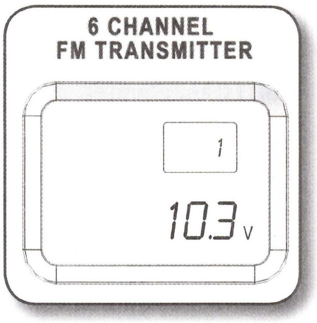


control subsystem

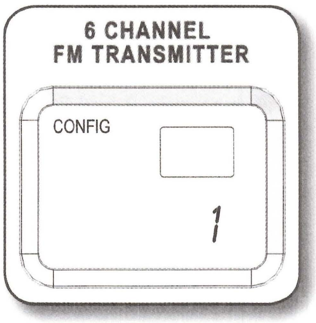
Basic Transmitter Operation

The Transmitter joysticks can be configured to work in two basic configurations. To check or switch between configurations, follow these instructions:

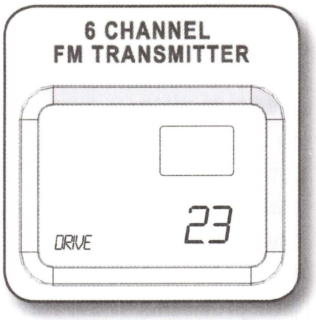
1. **Turn on the Transmitter** by pushing the power switch to the ON position.


6 CHANNEL
FM TRANSMITTER
1
10.3 v

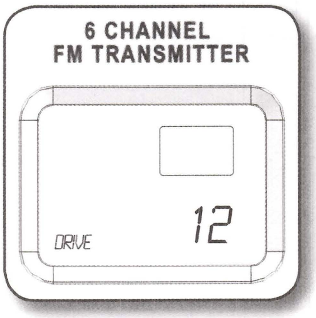
2. **Enter the menu** on the transmitter by holding down both the Mode and Select buttons next to the LCD until the menu opens.


6 CHANNEL
FM TRANSMITTER
CONFIG
1

3. **Enter the Driving Mode Adjustment menu** by pressing the Mode button until DRIVE is displayed on the left side (it's the last menu).


6 CHANNEL
FM TRANSMITTER
DRIVE
23

4. **The current driving mode is displayed.** This will be either "23" or "12". Push up or down toward either the + or – on the data input button on the right side of the LCD to switch between these two modes. The two modes are explained on the following pages.


6 CHANNEL
FM TRANSMITTER
DRIVE
12

control subsystem, continued

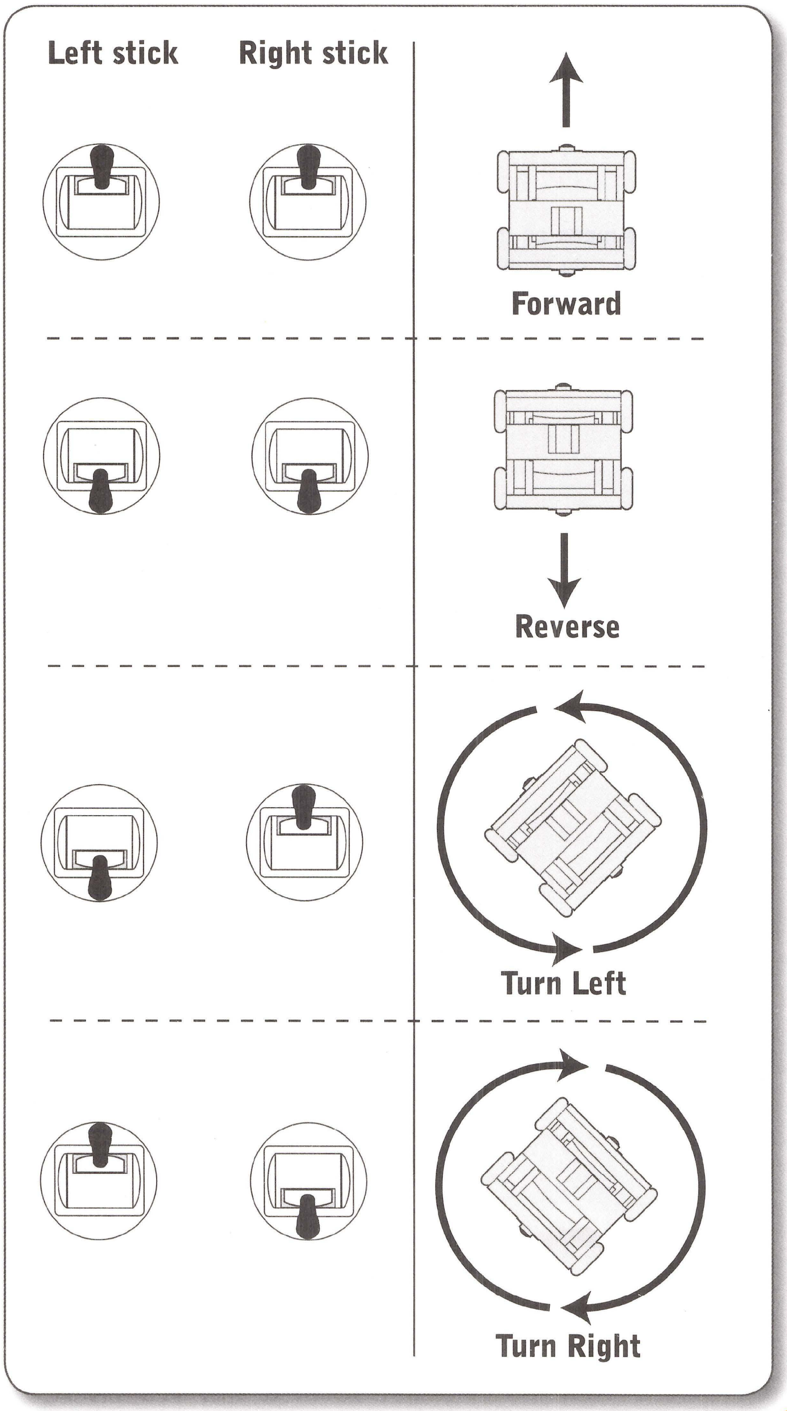
Configuration 1:
Tank-style control ("23" mode – default)

Note: Make sure there are no jumper clips on Analog/Digital Ports 13, 14, 15, or 16 on the Micro Controller, otherwise your robot's controls will behave differently from what is listed here in this section. For details on how to use these jumpers to configure advanced control features, visit the Logic Subsystem chapter.

This control configuration uses the vertical axes of both sticks to control the two motors independently. The name "23 mode" comes from the fact that the vertical axis of the right stick is "Control Channel 2", and the vertical axis of the left stick is "Control Channel 3", hence axes 2 and 3 ("23") are being used to drive.

In this configuration, the left stick controls the motor attached to Motor Port 3, and the right stick controls the motor attached to Motor Port 2.

Warning: Always make sure the transmitter is turned on and functioning before turning on the robot! If the transmitter is not on when the receiver is activated, the receiver may accidentally interpret other radio waves in the air as commands and cause the robot to move unexpectedly!



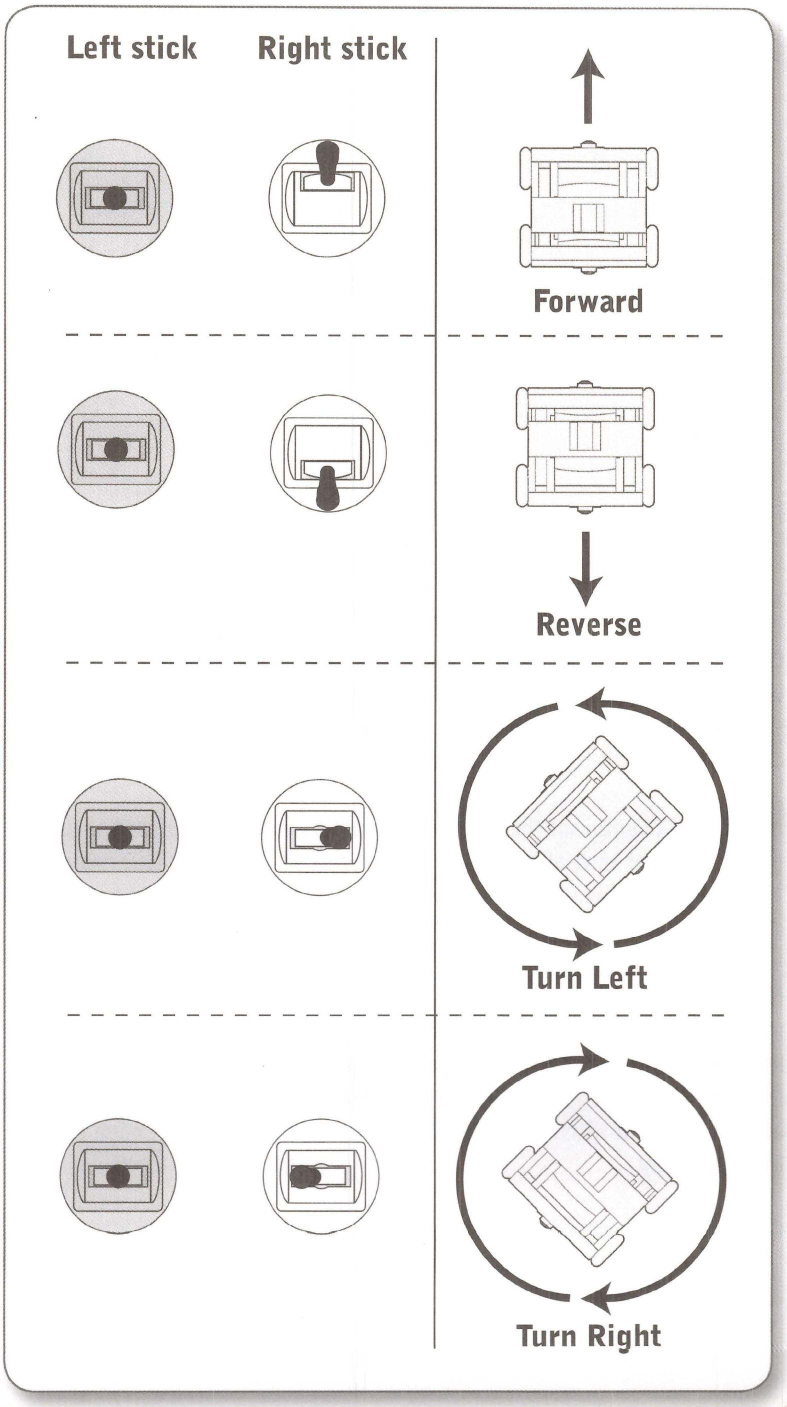
control subsystem, continued

Configuration 2:
Arcade-style control ("12" mode)

Note: Make sure there are no jumper clips on Analog/Digital Ports 13, 14, 15, or 16 on the Micro Controller, otherwise your robot's controls will behave differently from what is listed here in this section. For details on how to use these jumpers to configure advanced control features, visit the Logic Subsystem chapter.

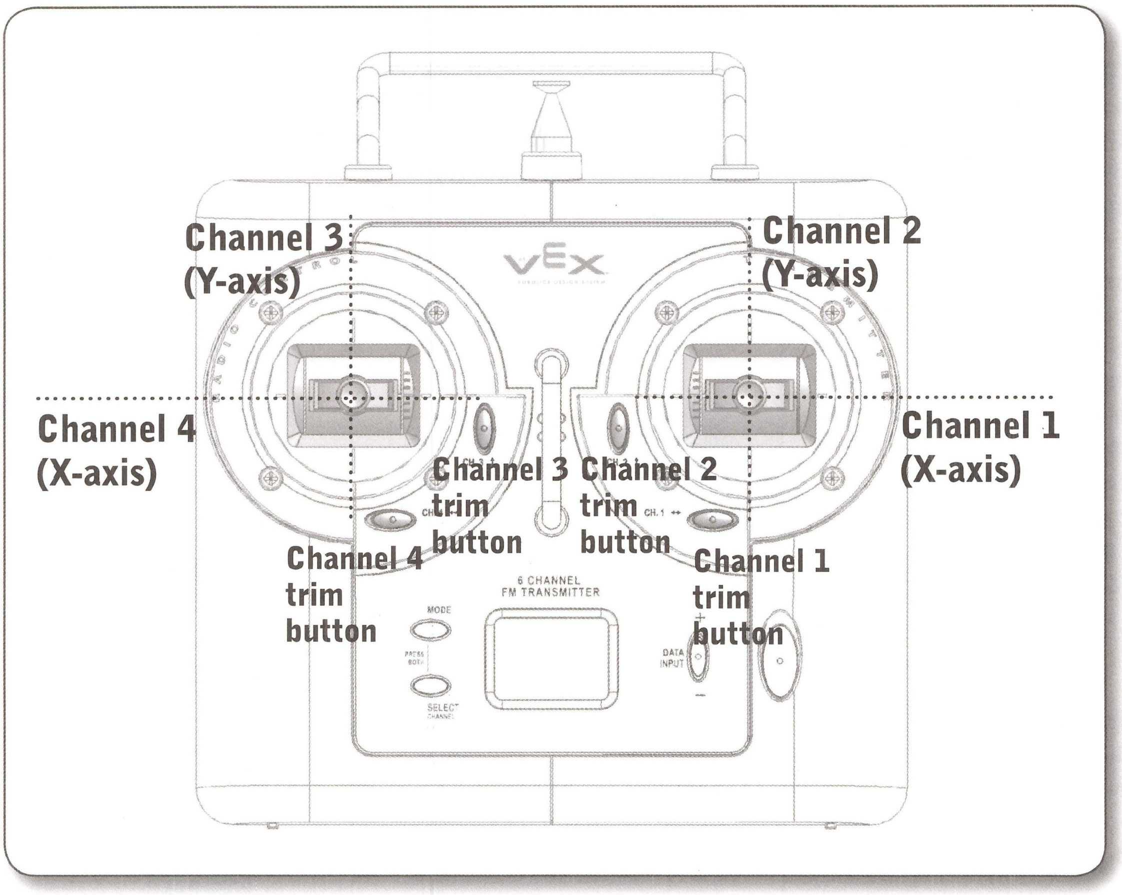
This control configuration uses only the right joystick to control both forward/back motion and turning motion. The name "12 mode" comes from the fact that the horizontal axis of the right stick is "Control Channel 1", and the vertical axis is "Control Channel 2", hence axes 1 and 2 ("12") are being used to drive.

In this configuration, the right stick controls both throttle and turning.



control subsystem, continued

Transmitter Trim


Channel 3
(Y-axis)
Channel 2
(Y-axis)
Channel 4
(X-axis)
Channel 1
(X-axis)
Channel 3 trim button
Channel 2 trim button
Channel 4 trim button
Channel 1 trim button
6 CHANNEL FM TRANSMITTER
MODE
SELECT
DATA INPUT

Because the sticks on the transmitter are analog electromechanical devices that operate directly on circuit voltage, there is the distinct possibility that the sticks will become miscalibrated. This happens when the sticks start delivering different voltages than what the controller expects for a given position.

In order to counteract this problem, there are manual adjustment buttons on the transmitter that allow you to recalibrate or "recenter" the transmitter. These can be adjusted so that the voltages match up correctly again on the stick.

Note that each stick's position actually breaks down into two separate measurements. One of them indicates how far left and right the stick is (the horizontal, or "X", axis), and the other measures where it is with respect to the vertical, or "Y", axis. These four axes (two axes times two sticks) can become miscalibrated separately, so you may need to adjust each of them independently.

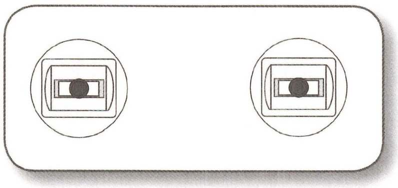
Conveniently, each axis is assigned a number (which corresponds with the "control channel" that it works on), so there should be no confusion between which axis or stick is which.

control subsystem, continued

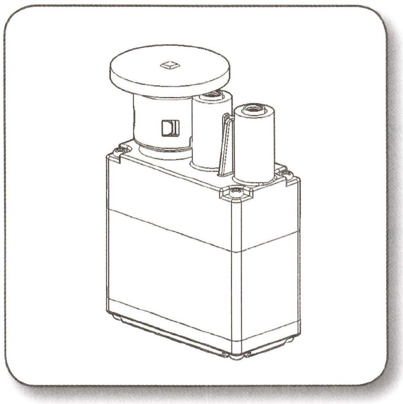
Transmitter Trim, continued

To calibrate the sticks:

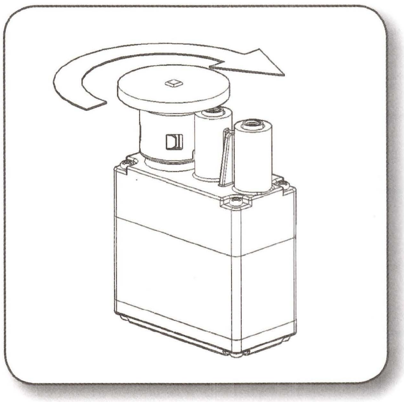
1. **Release both control sticks** so they return to their neutral positions.



2. **Hold the robot** (or just the motors, if they are not mounted) up in the air so you can see whether the motors are turning or not, and whether the servomotors are in the centered positions or not.

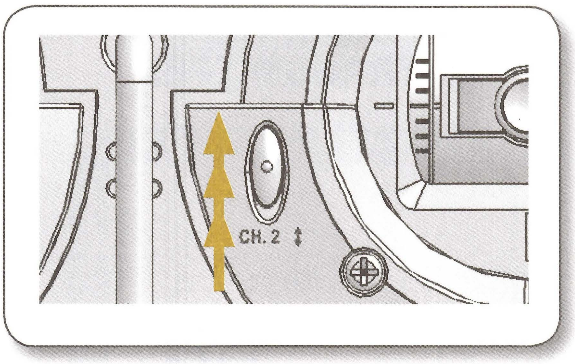


3. **If you see a motor turning** or a servomotor not centered, follow the wire back to the Micro Controller to see which port it is plugged into.



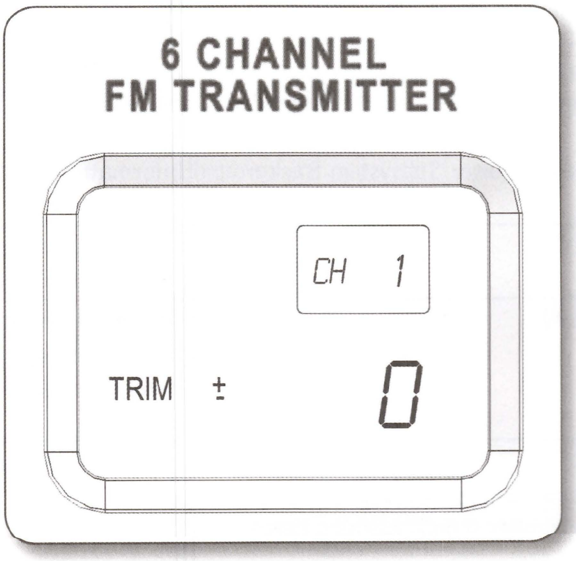
4. **Consult the Joystick Mappings** section to see which transmitter axis controls that particular port (this will depend on the Driving mode you are in).

5. **Push either direction** on the Trim Button for that axis to try and correct the problem.



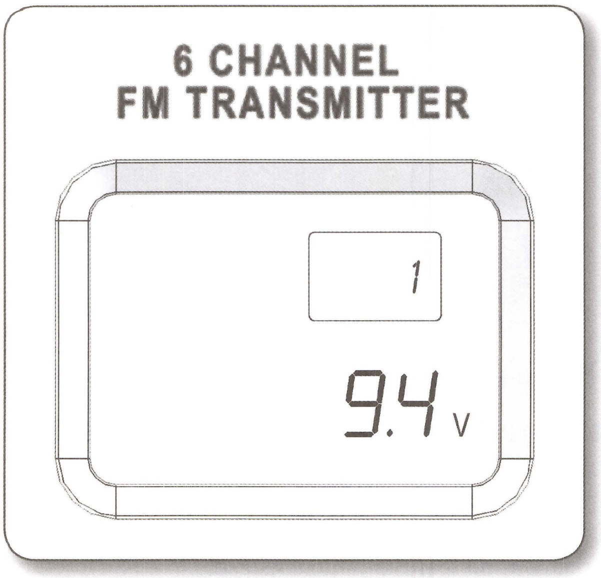
6. **Check if the motors slowed down** or got closer to center. If they did, then keep pushing the button in that direction until they are stopped/centered; if they get faster or farther from center, push the other way on the trim button instead.

7. **If you cannot get the motors to stop** because the "stop" position seems to be in between two trim settings, finer adjustments are available. Go into the menu (hold both the Select and Mode buttons for one second), and adjust the appropriate channel from the TRIM menu (push Mode until TRIM is displayed, then Select until the channel you want is displayed, then use the Data Input lever on the right to make adjustments).



control subsystem, continued

Transmitter Battery Voltage



In normal operation, the transmitter displays two numbers on the LCD screen: the configuration number (see Appendix G), and the battery voltage on the transmitter. Note that this screen only displays the battery power left on the transmitter, and not the robot! There is no way to monitor the robot's battery voltage using this display, so you will need to watch separately for problems arising from low robot battery power.

The transmitter's power begins to decrease at approximately 9.4V on the display. If you are at 9.4V or less, consider stopping and recharging the transmitter batteries. If the voltage reaches 8.9V, you have about 10 minutes left before you hit low voltage, so you should stop if possible. The transmitter hits low voltage at 8.5V on the display. At this point, you will hear a beeping sound, a low battery indicator will appear, and performance will begin to degrade significantly. You should stop and recharge the batteries at this point.

See the Power Subsystem Background Information for details.

9.4V	Batteries somewhat low. You will need to stop soon.
8.9V	Batteries very low (10 minutes or less remaining), stop unless absolutely necessary.
8.5V (Low battery indicator comes on, controller sounds warning beep)	Batteries depleted. Stop now.

control subsystem, continued

Stick Mode

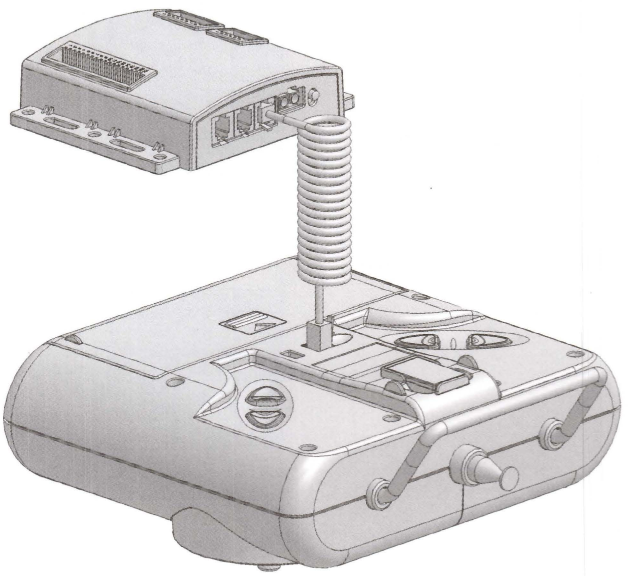
Stick Mode configuration is accessed differently from the other menus. To access this mode, you must hold down Mode and Select while turning the transmitter on, rather than pressing them once it is already on.

The only option you can change is the Stick Mode, between "2" and "1". 2 is the default, and you should leave it this way unless you have a specific reason for changing it. Setting the Stick Mode to 1 will swap axes 2 and 3, so the vertical axis of the left stick becomes channel 2, and the vertical axis of the right stick becomes channel 3. Unless you have a good reason to change this, you should leave the Stick Mode on 2.

Tether Port

Sometimes for diagnostic purposes, it may be useful to plug the transmitter directly into the micro controller, and bypass the need for the RF Receiver. This would help you determine, for instance, whether radio interference is at fault for your robot behaving strangely, or if some other factor is to blame.

In order to use the tether feature, you will need to purchase a cable. Any telephone handset extension cable should work (the cable that goes from the handset to the base of a corded phone, not the cable that goes from the phone to the wall).

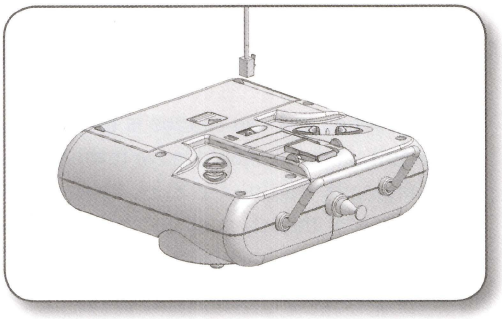


control subsystem, continued

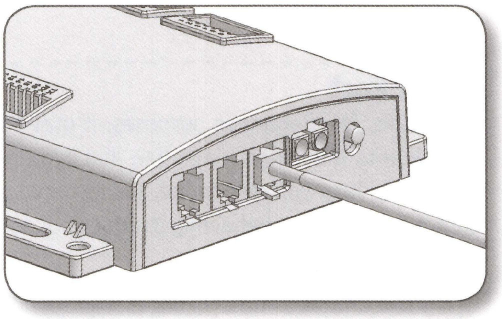
Tether Port, continued

To use the tether feature:

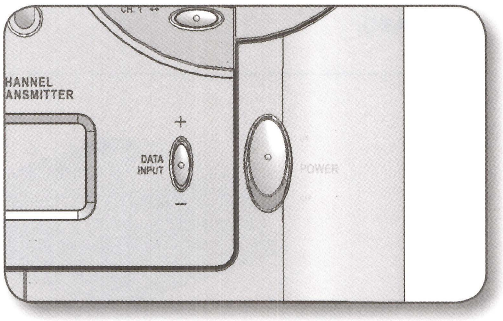
1. Hook up one end of the cable to the back of your Radio Transmitter, in the port marked "Tether Port".



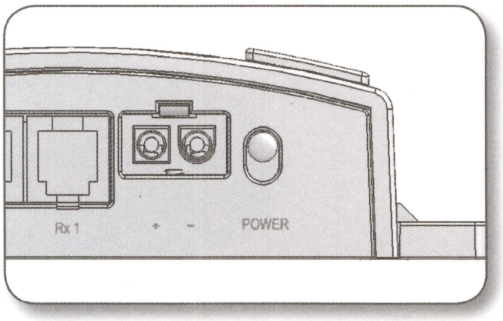
2. Plug the other end directly into the Rx1 port of your Micro Controller.



3. Turn the Transmitter on by pushing the power switch on the Transmitter to the ON position.



4. Turn the Micro Controller on by flipping the power switch on the Micro Controller to the ON position.

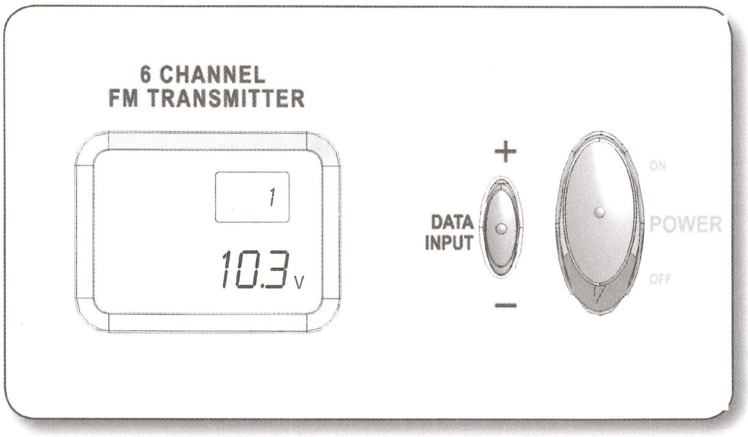


5. Test your robot. The controls should operate exactly as they would remotely over radio, but without the possibility of radio interference or other similar issues.

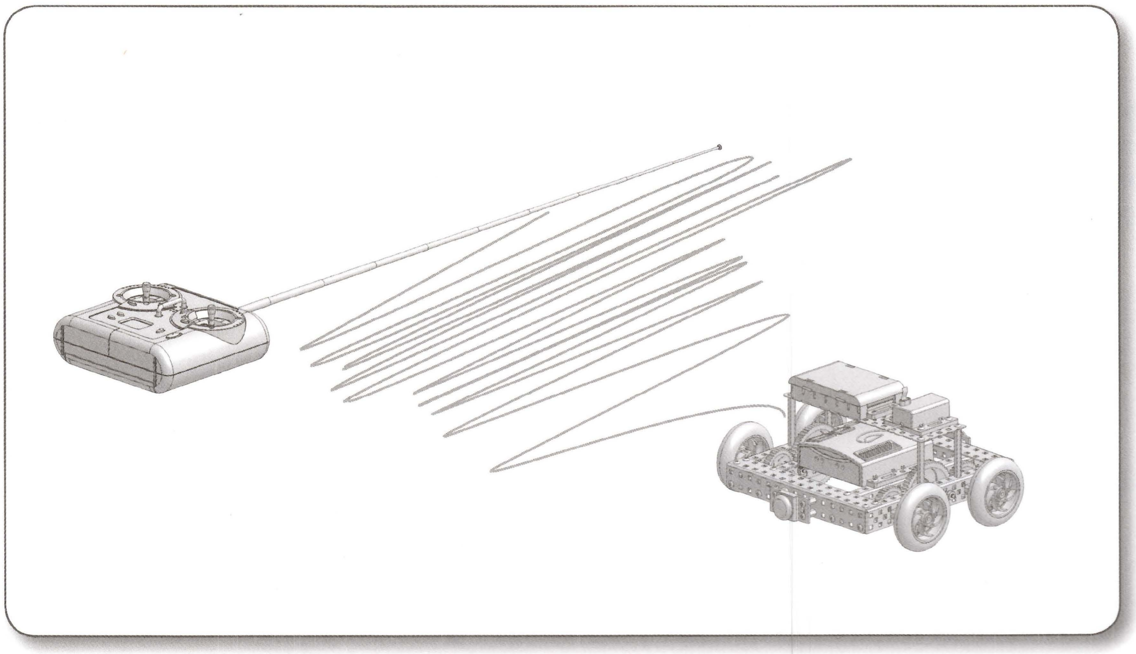
control subsystem, continued

Tips

Always turn the Transmitter on before powering up the robot. If the transmitter is not on when the receiver is activated, the receiver may accidentally interpret other radio waves in the air as commands and cause the robot to move unexpectedly!



Radio waves radiate out from the sides of the transmitter antenna, not from the tip. For this reason, you will get the best range and performance from your transmitter if you don't point it directly at your robot.

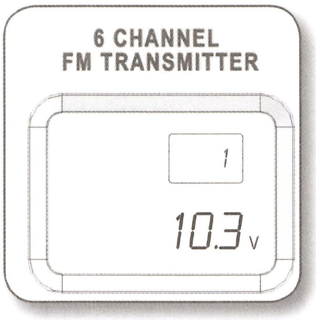


control subsystem, continued

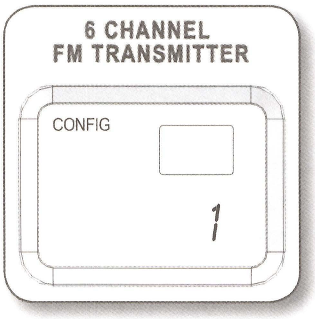
Tips, continued

If you accidentally change a setting on your controller that you didn't want to change, you can reset the controls through the CONFIG menu.

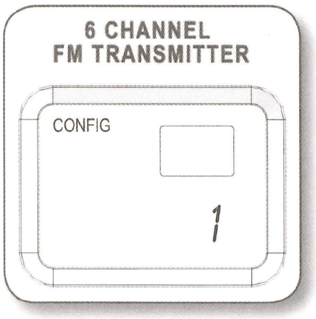
1. **Turn the transmitter on** by pushing the power switch into the ON position.


6 CHANNEL
FM TRANSMITTER
1
10.3 V

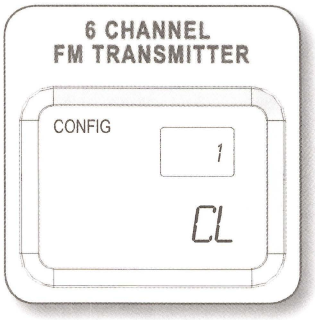
2. **Hold down the Mode and Select buttons** for two seconds until the menu appears. CONFIG should be selected by default.


6 CHANNEL
FM TRANSMITTER
CONFIG
1

3. **If you wish to reset the data** for a different robot configuration, press the + button on the Data Input button until the configuration number you want is displayed. If you are not using multiple configurations (see Appendix G), then ignore this step.


6 CHANNEL
FM TRANSMITTER
CONFIG
1

4. **Press the Select button**. The letters CL (for "clear") should appear.


6 CHANNEL
FM TRANSMITTER
CONFIG
1
CL

5. **Push up or down** toward the + or – on the Data Input button and hold for 2 seconds to reset the controls for the selected config number. The Transmitter will beep when the configuration is reset.

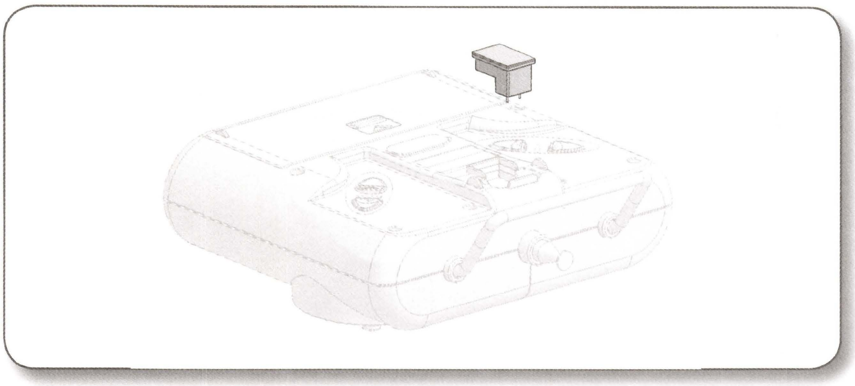
control subsystem, continued

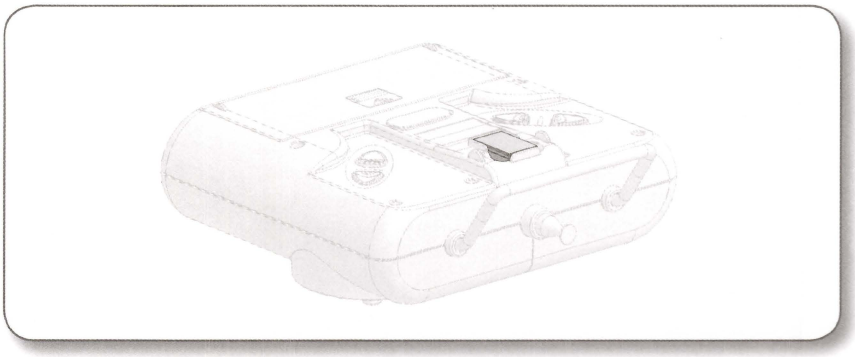
Tips, continued

Remember that the transmitter does not monitor robot battery voltage, only its own transmitter battery. Watch the robot to see if it seems to be low on power.

If more than one robot is operating in the same area, be sure that the robots are operating on different frequencies or their commands will interfere with each other (see Frequency Crystals in Background Information in this chapter).

If you own more than one set of frequency crystals, be sure that the frequency module in your transmitter matches the crystal in your RF receiver module (see Frequency Crystals in Background Information in this chapter).





The FCC Wants You to Know
This equipment has been tested and found to comply with the limits for radio controlled devices, pursuant to Part 15 and Part 95 of the *FCC Rules*. These limits are designed to provide reasonable protection against harmful interference. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

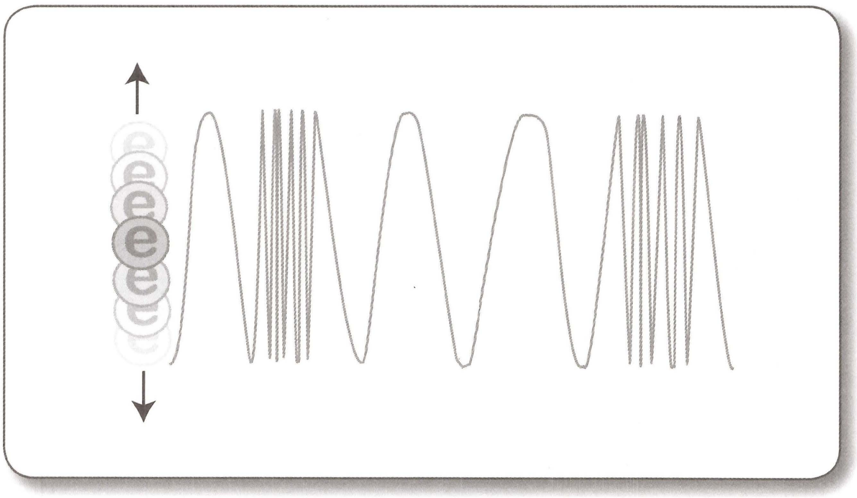
- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Consult your local electronics store or an experienceds radio/TV technician for help.
- If you cannot eliminate the interference, the FCC requires that you stop using your R/C transmitter.

Warning: Changes or modifications not expressly approved by Innovation One may cause interference and void the user's authority to operate the equipment. Only use authorized crystals designed for use with the Vex Robotics Design System RF Receiver.

concepts to understand

Electromagnetic Waves

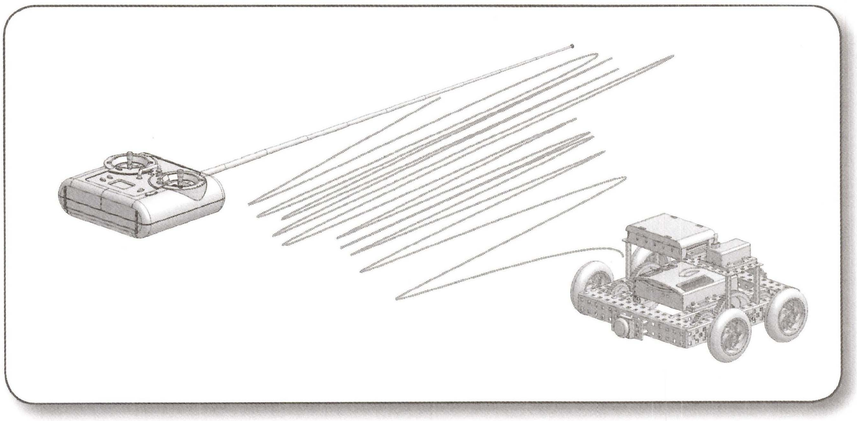
When electrons accelerate, they radiate an electromagnetic signal that moves at the speed of light. By accelerating and decelerating electrons in a controlled pattern, a wave pattern can be generated in the radiated electromagnetic field. These are called electromagnetic waves. Electromagnetic waves move at the speed of light, and are therefore very good at carrying information quickly from one place to another.



concepts to understand, continued

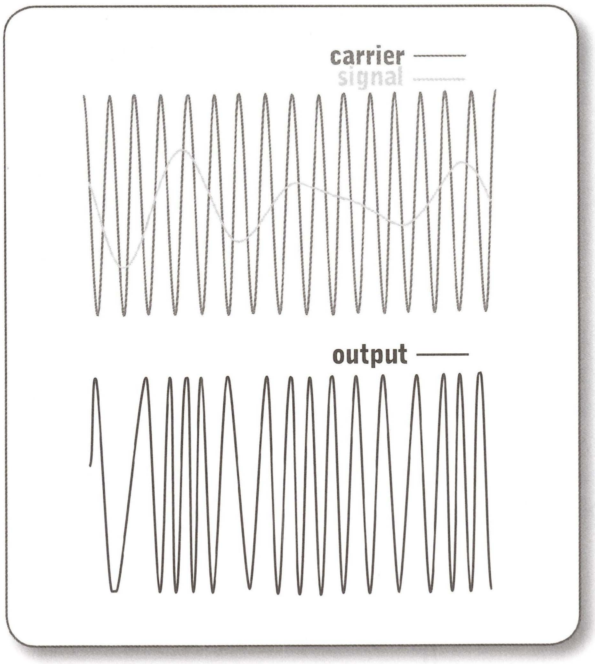
Frequency-Modulated Signals

The Vex Radio Transmitter uses an electromagnetic wave with a certain frequency to transmit data to the RF receiver module. Frequency modulation (FM) is a way of encoding information in wave patterns such as these.



Waves have several basic properties, including amplitude and frequency. In frequency modulation, the frequency of the basic wave, known as a carrier wave, is modified by combining it with another signal known as the modulating wave, which produces a final wave that looks irregular, but is really carrying the data from the signal wave on top of the carrier wave.

FM is less susceptible to interference than other radio transmission methods, such as amplitude modulation (AM) or direct transmission of the signal wave.



concepts to understand, continued

Radio Frequencies

Since every FM signal has a set carrier wave frequency, different carrier waves can be used to carry different signals at the same time without causing interference. The air around you is filled with a multitude of different FM wave frequencies being sent from many sources, and they don't interfere with each other, because their carrier waves all have different frequencies.

To prevent chaos, there are a limited number of frequencies that can be used for radio control. In the US, the Federal Communications Commission (FCC) is responsible for distributing these frequencies among the various industries that want to use RC. Ground vehicles operating by FM radio control have been assigned the 75MHz band and must transmit their control information using a carrier frequency that is between 75MHz and 76Mhz.

Radio Channels

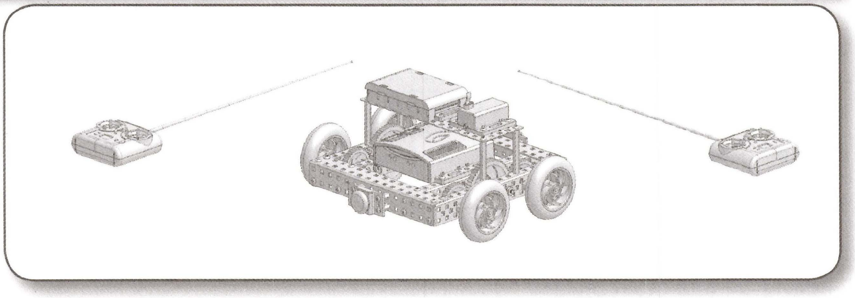
Exact frequencies (which have names like 75.410MHz) are often hard to remember, or inconvenient to talk about. The frequencies that are used to transmit data in the 75MHz band are therefore also assigned channel numbers. A channel is like a nickname for a certain frequency. The carrier frequency 75.410MHz, for instance, can also be called Channel 61 for convenience.

Be careful with the term channel, however, because the term is also used to refer to "control channels," which are used to number the inputs on the transmitter (each joystick has two control channels, for instance: one for the x-axis and one for the y-axis). You will need to infer from usage context whether "channel" is being used to refer to a "radio frequency channel" (frequency) or a "control channel" (axis).

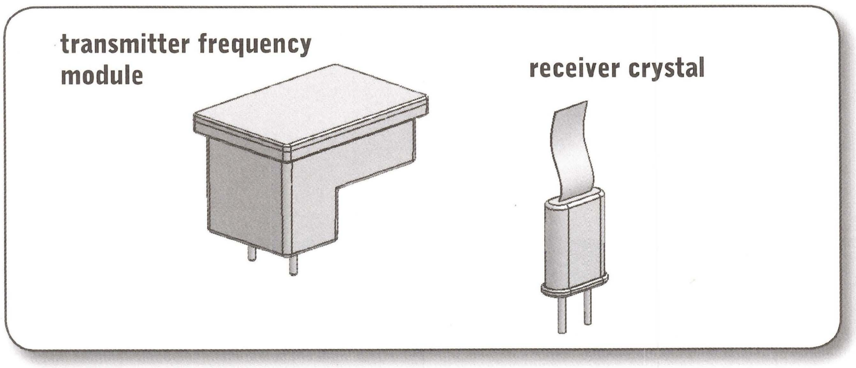
concepts to understand, continued

Frequency Crystals

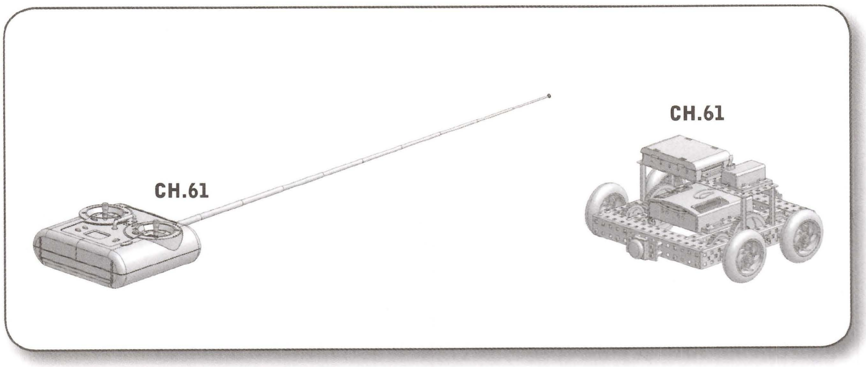
When more than one Transmitter is running in the same area (e.g. during a competition), there is potential for trouble. How can the robot determine which transmitter is sending which signal?



If all Vex Radio Transmitters and RF Receivers were to operate on the same frequency, then there would be no way for the robot to discriminate between signals. However, the Vex Radio Transmitter and Receivers are designed to be able to use a number of different FM carrier frequencies (see Radio Frequencies above). As long as each transmitter-receiver pair uses a different frequency, the robots won't get confused.



The Radio Transmitter and RF Receiver are set frequencies according to a special radio frequency crystal that is installed in them. A transmitter frequency module and RF receiver crystal set comes pre-installed in both the Transmitter and Receiver, but they are modular, and can be removed and replaced only with a Vex approved transmitter frequency module and matching RF reciever crystal. All Starter Kits transmit and receive on the same frequency, so in order to compete in an environment with multiple robots or to use multiple transmitters, you will need to replace at least one transmitter frequency module and RF receiver crystal.



concepts to understand, continued

Frequency Crystals, continued

Remember, crystals come in pairs! The crystal in the transmitter frequency module determines what frequency it will use to send commands, and the RF receiver crystal tells it what frequency to listen on. If the crystals in the transmitter and the receiver don't match, they will not be able to communicate. Always use crystals of the same frequency on both the transmitter and receiver for a given robot.

Crystals available for use with the Vex Robotics Design System

Starter kit	= Ch. 61 (75.410MHz)
TX/RX Upgrade	= Ch. 89 (75.970MHz)
Additional Crystal Kit #1	= Ch. 65, 69, 81, 85 (75.490, 75.570, 75.810, 75.890MHz)
Additional Crystal Kit #2 (Web Only)	= Ch. 63, 67, 83, 87 (75.450, 75.530, 75.850, 75.930MHz)

Inventors should only use Vex authorized RF receiver crystals and transmitter frequency modules.

Joystick Mechanism

The joysticks on the radio control transmitter are actually part of a variable resistor component in the transmitter circuit. Pushing the sticks in one direction or another changes the electrical resistance of a potentiometer inside the transmitter, which in turn causes a change in voltage. The transmitter will then send a different signal to the receiver based on this voltage. For instance, the transmitter may expect the sticks to provide a resistance that produces a voltage of 4.8V when centered.

Miscalibration occurs when the joystick circuit does not generate the expected voltage for a given position of the sticks. For any number of reasons, from manufacturing tolerances to battery voltage drop, the sticks may start providing a different number while centered, say 3.7V.

The transmitter will have no idea what is causing the 3.7V, so it will assume that it is because the stick is in the position that would normally produce a 3.7V reading. It will send a signal to the receiver indicating that the stick is in the 3.7V position. Clearly, this is not correct, and this miscommunication will cause the robot to behave oddly, because it will be responding to commands that aren't actually being given on the stick. "Trim Setting Adjustment" instructions (pages 6-12) will correct this condition.

subsystem interactions

How does the Control Subsystem interact with...

...the Structure Subsystem?

- The structure subsystem will generally provide a place to store the RF Receiver module on the robot.
- On Squarebot, the structure subsystem provides an elevated deck for the RF Receiver Module to be mounted for enhanced reception.

...the Motion Subsystem?

- Unlike radio-controlled cars, the Vex robot does not directly tie the Control Subsystem into the Motion Subsystem. The commands generated by the operator using the Transmitter are sent to the radio receiver on the robot, but from there, the commands are given to the Micro Controller, which takes this and other information into account when deciding which command to give to the Motion components.

...the Power Subsystem?

- Broadcasting radio waves takes a significant amount of electrical power. The 8 AA batteries (or 9.6V battery pack) installed in the Vex Transmitter provide the Transmitter with all the power it needs to operate its internal circuitry and send out radio waves carrying commands to the receiver.
- The RF Receiver mounted onboard the robot, on the other hand, draws its power from the Power Subsystem indirectly, through the Micro Controller (which is part of the Logic Subsystem).

...the Sensor Subsystem?

- The Control and Sensor Subsystems complement each other to achieve better control of the robot. The Control Subsystem provides human control over the robot, but the human operator does not always have perfect control, or the perfect point of view to see the robot's position. The Sensor Subsystem gives the robot the ability to make its own informed decisions, and can be a substantial aid to the human operator.

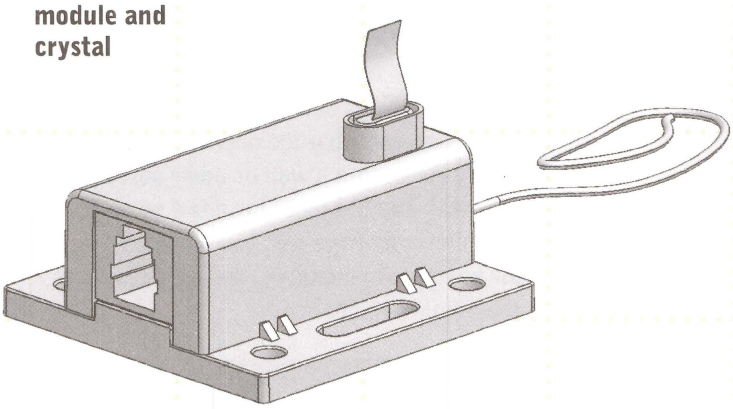
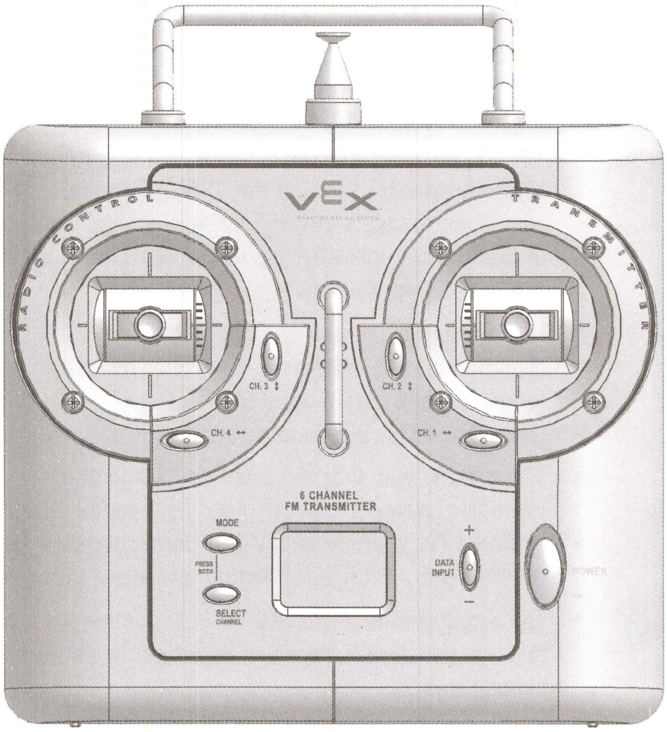
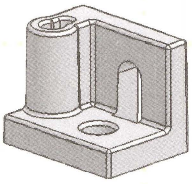
...the Sensor Subsystem, continued

- On Squarebot, the bumper sensors function as both tag game sensors and as emergency stop triggers. In the event that the operator accidentally drives into a wall or other obstacle, the sensor will stop the robot for a few seconds to prevent motor damage that could occur if the operator attempts to continue running the motors when the robot is stuck.

... the Logic Subsystem?

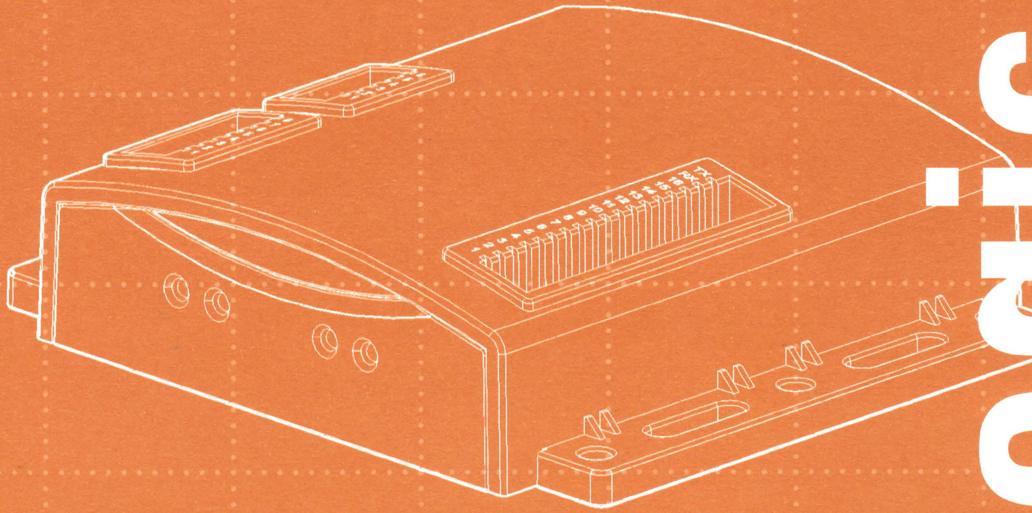
- The Micro Controller module controls the flow of commands from the human operator to the robot. The Micro Controller ultimately decides whether to pass joystick commands on to the motors, to modify them, or to override them, based on its programmed behavior and other information available to it (from sensors, for instance).
- The RF Receiver module is connected to the Vex Micro Controller through the 9″ RJ-10 cable that runs from the back of the Receiver into the front of the Micro Controller. Up to two receivers can be supported simultaneously.
- If desired, the Transmitter can be hooked directly into the Vex Micro Controller using a tether cable, bypassing the RF Receiver (see the Control Subsystem chapter for details).
- The specific way that the robot will respond to joystick movement is determined by a combination of Radio Transmitter and Micro Controller settings. See Appendix F for a full listing of control layouts.
- The Squarebot receives user driving commands through the the RF Receiver, and uses the default control layout.

control subsystem inventory

component	qty
RF Receiver module and crystal 	1
radio transmitter  VEX RADIO CONTROL TRANSMITTER CH. 3 CH. 2 CH. 4 CH. 1 6 CHANNEL FM TRANSMITTER MODE PRESS BOTH SELECT CHANNEL + DATA INPUT − POWER	1
receiver antenna sleeve holder 	1

component	qty
receiver antenna sleeve 	1

The Logic Subsystem has just one major component, the Vex Micro Controller. The controller is the most integral component of the entire Vex system, because it coordinates and controls all the other components. The Logic Subsystem is effectively the robot's brain.



logic

logic

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squarebot logic subsystem parts & assembly 7.1

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subsystems interfaces 7.20

logic subsystem inventory 7.21

squarebot logic subsystem parts & assembly

The Vex Micro Controller coordinates the flow of information and power on the robot. All other electronic system components must be connected to the Micro Controller in order to function.

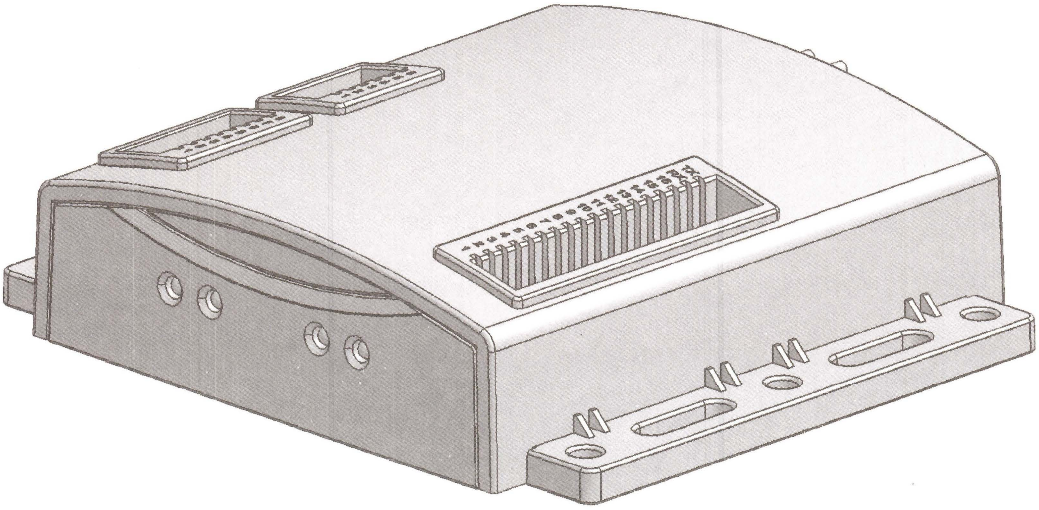
It helps to do the assembly steps for the Logic Subsystem last when building your robot, because all the plugging-in of components will take place in this section. It would make the most sense if those parts were already attached to the robot before plugging them in.

① **Collect and identify the parts from the list of materials below:**

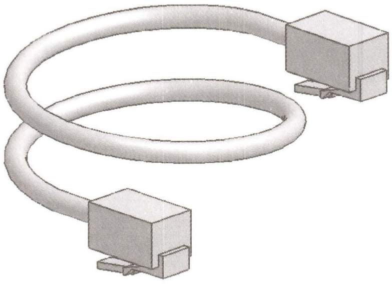
materials	qty
micro controller module	1
RJ-10 cable for receiver(s)	1
8-32 hex screw, ½″	4
keps nut	4

squarebot logic subsystem parts & assembly, continued

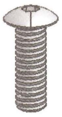
micro controller module x 1



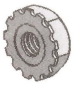
RJ-10 cable for receiver x 1



8-32 hex screw, ½" x 4



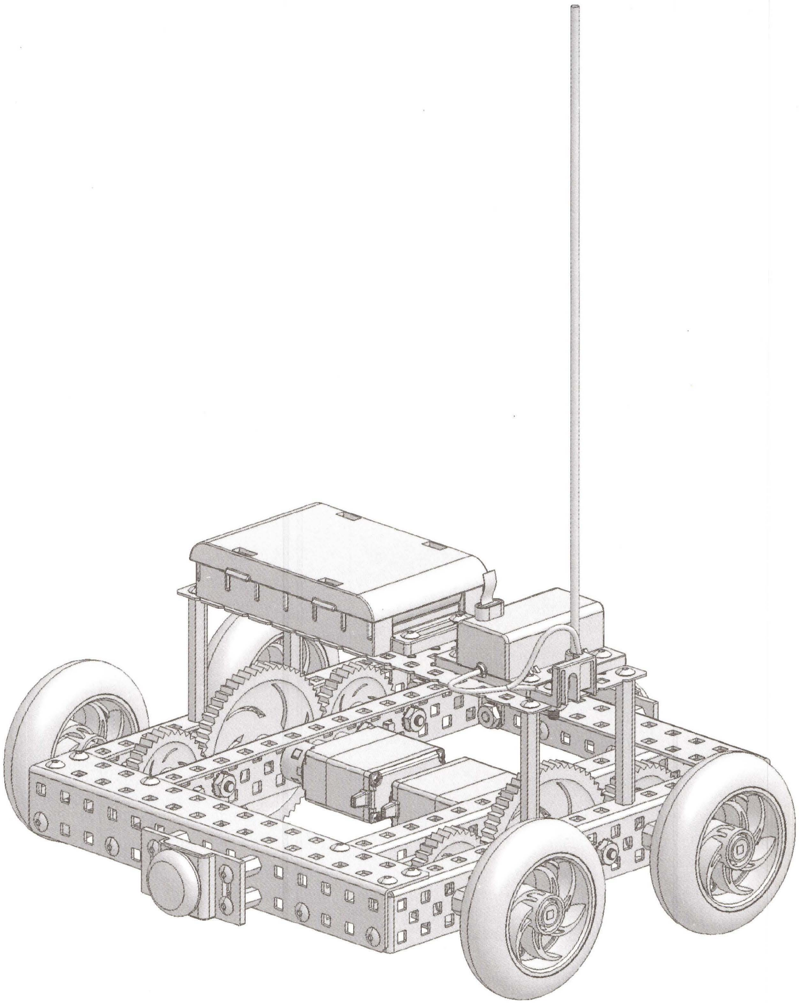
keps nut x 4



squarebot logic subsystem parts & assembly, continued

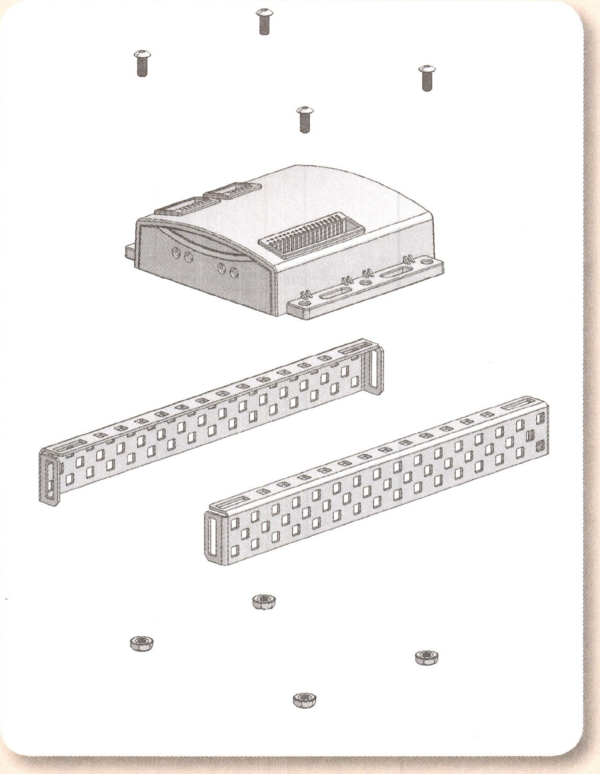
2 Attach the Vex Micro Controller Module

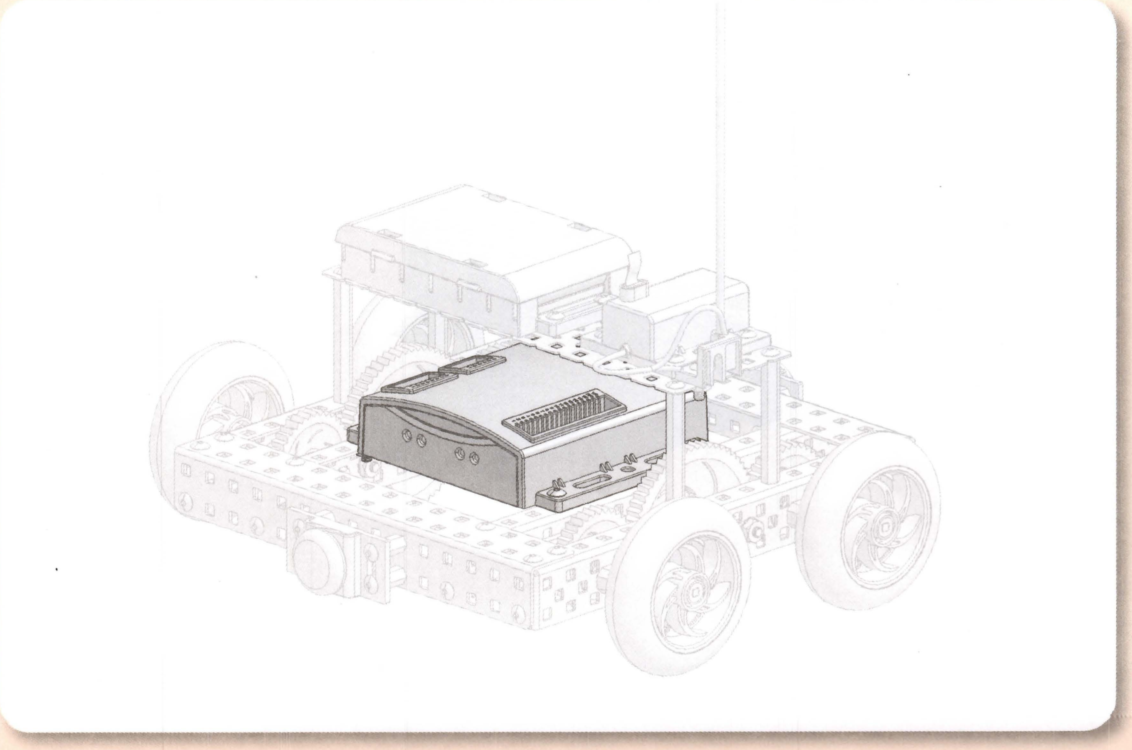
Begin by connecting the other subsystems to the robot. This is not absolutely necessary, but it will make more sense if all the other parts are already on board when it's time to plug them in.



squarebot logic subsystem parts & assembly, continued

2 Attach the Vex Micro Controller Module, continued



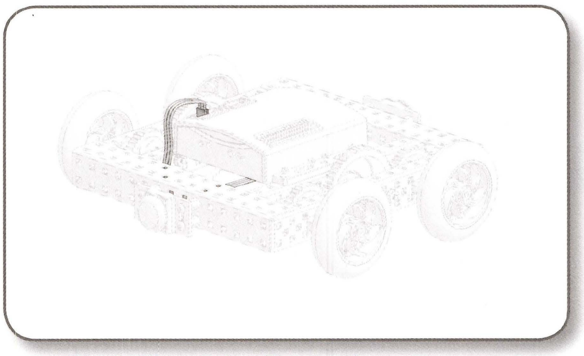


squarebot logic parts & assembly, continued

3 Connect components to the Micro Controller

Now that the Micro Controller is attached to the robot's structure, it's time to start connecting it to the other subsystems.

Begin by plugging the robot's left motor into port number 3 in the Motors section. The Micro Controller is at the "rear" of the robot, so the left motor is the one in the foreground in the picture. Take the wire that is attached to the motor, and plug the green connector into Motor Port 3.



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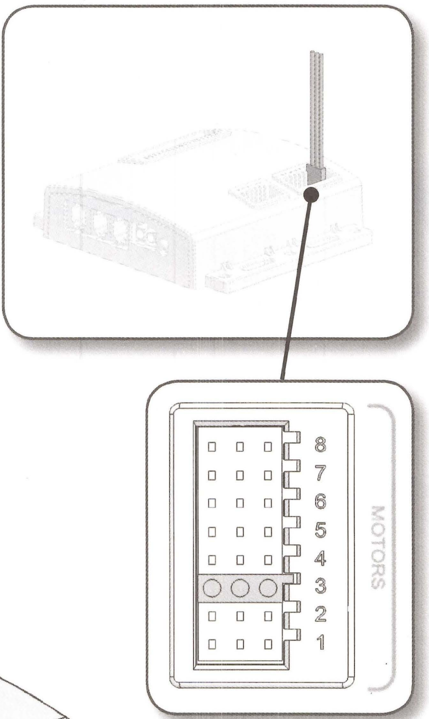
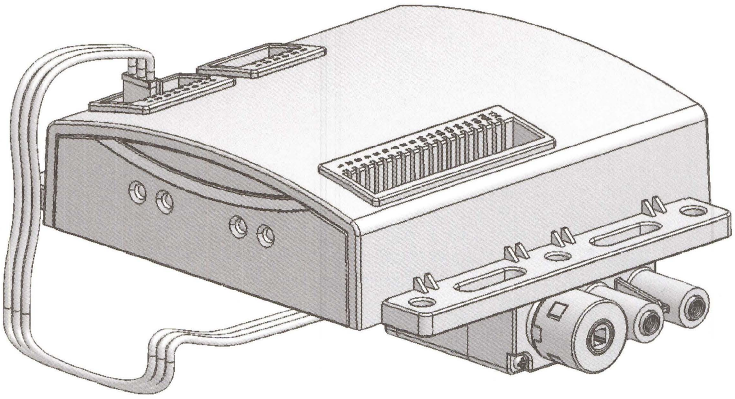


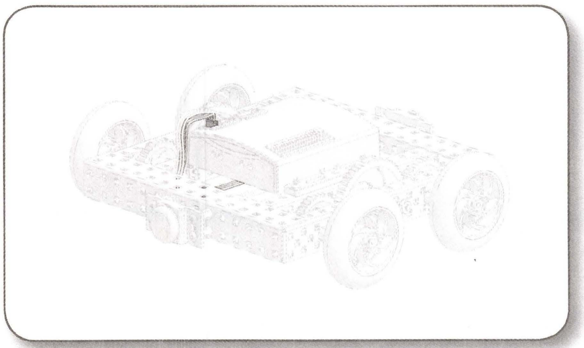


squarebot logic parts & assembly, continued

3 Connect components to the Micro Controller, continued

Next, plug the right motor into port number 2 in the Motors area.

Take the wire that is attached to the motor, and plug the green connector into Motor Port 2.



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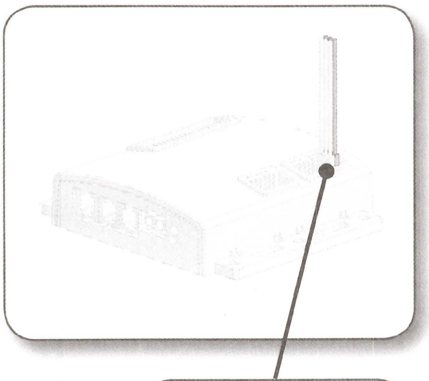
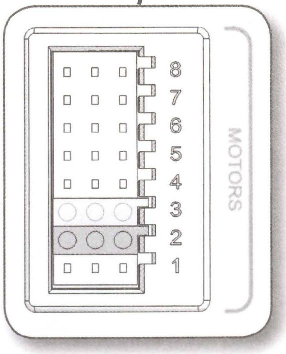
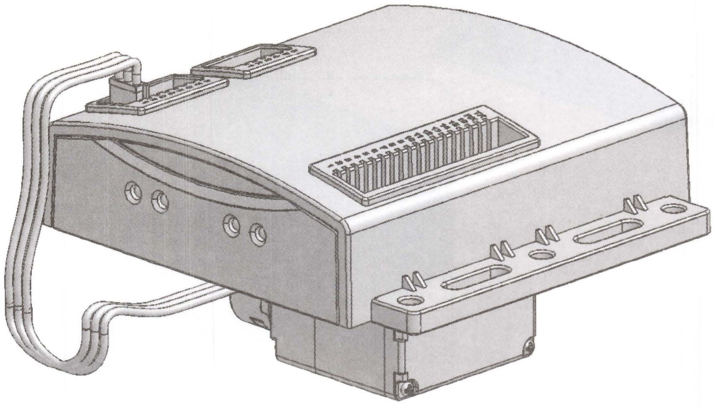






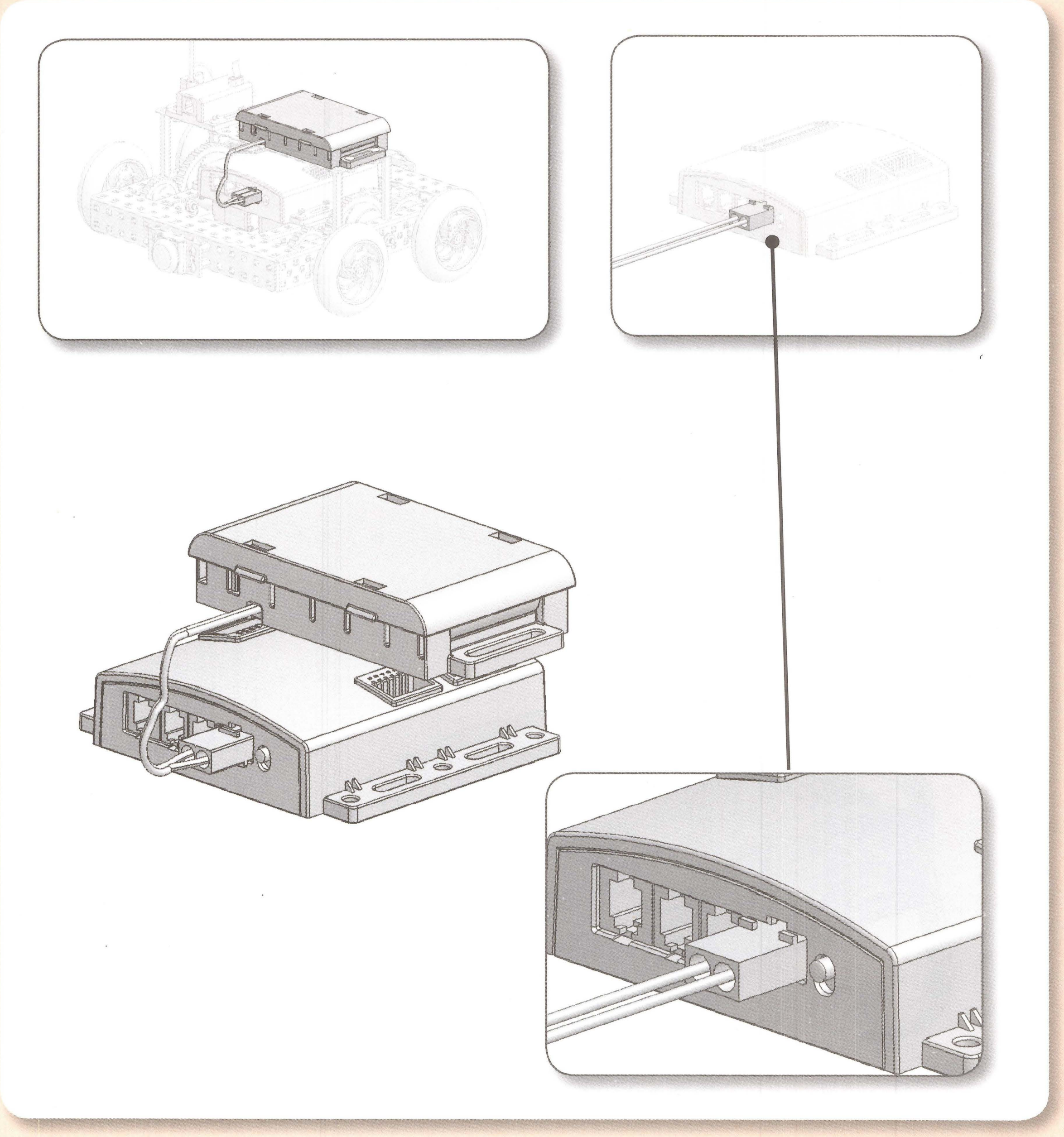
(left motor hidden for illustrative purposes)

The Motion Subsystem is now connected to the Logic Subsystem.

squarebot logic parts & assembly, continued

3 Connect components to the Micro Controller

Plug the Battery Holder into the front-facing side of the Robot Controller. Take the wire that is coming out of the Battery Holder, and plug the connector into the matching white port on the rear of the Micro Controller.

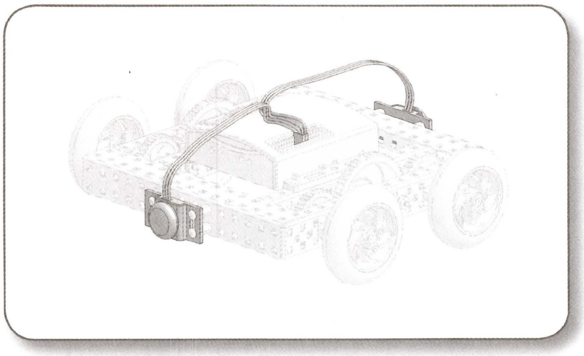


The Power Subsystem is now connected to the Logic Subsystem.

squarebot logic parts & assembly, continued

3 Connect components to the Micro Controller, continued

Plug the Bumper Switch Sensors into ports 9 and 10 in the Analog/Digital port bank. Take the wires coming out of the sensors, and plug them into Analog/Digital Ports 9 and 10. It dosen't matter which sensor goes into which port because Ports 9 and 10 are emergency stop ports.



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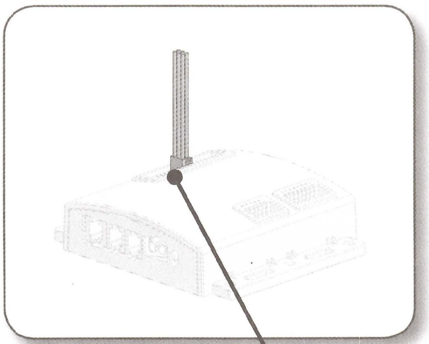
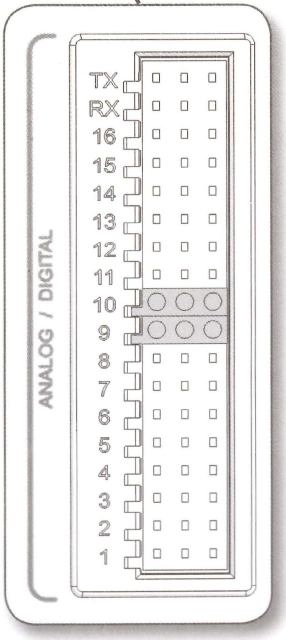
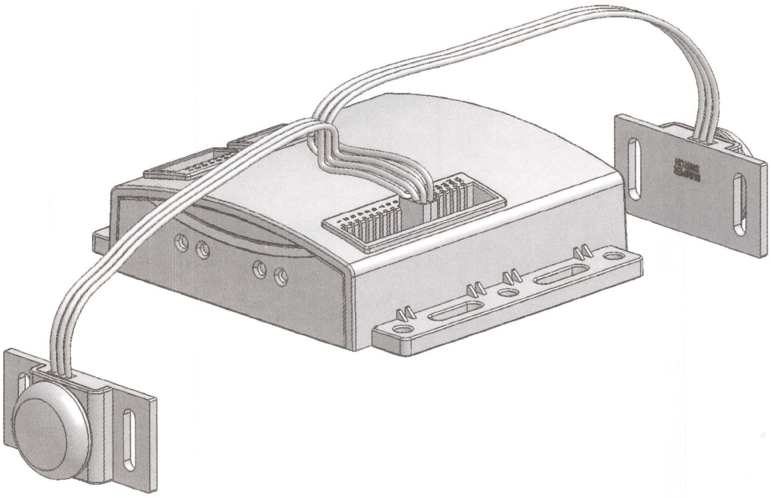




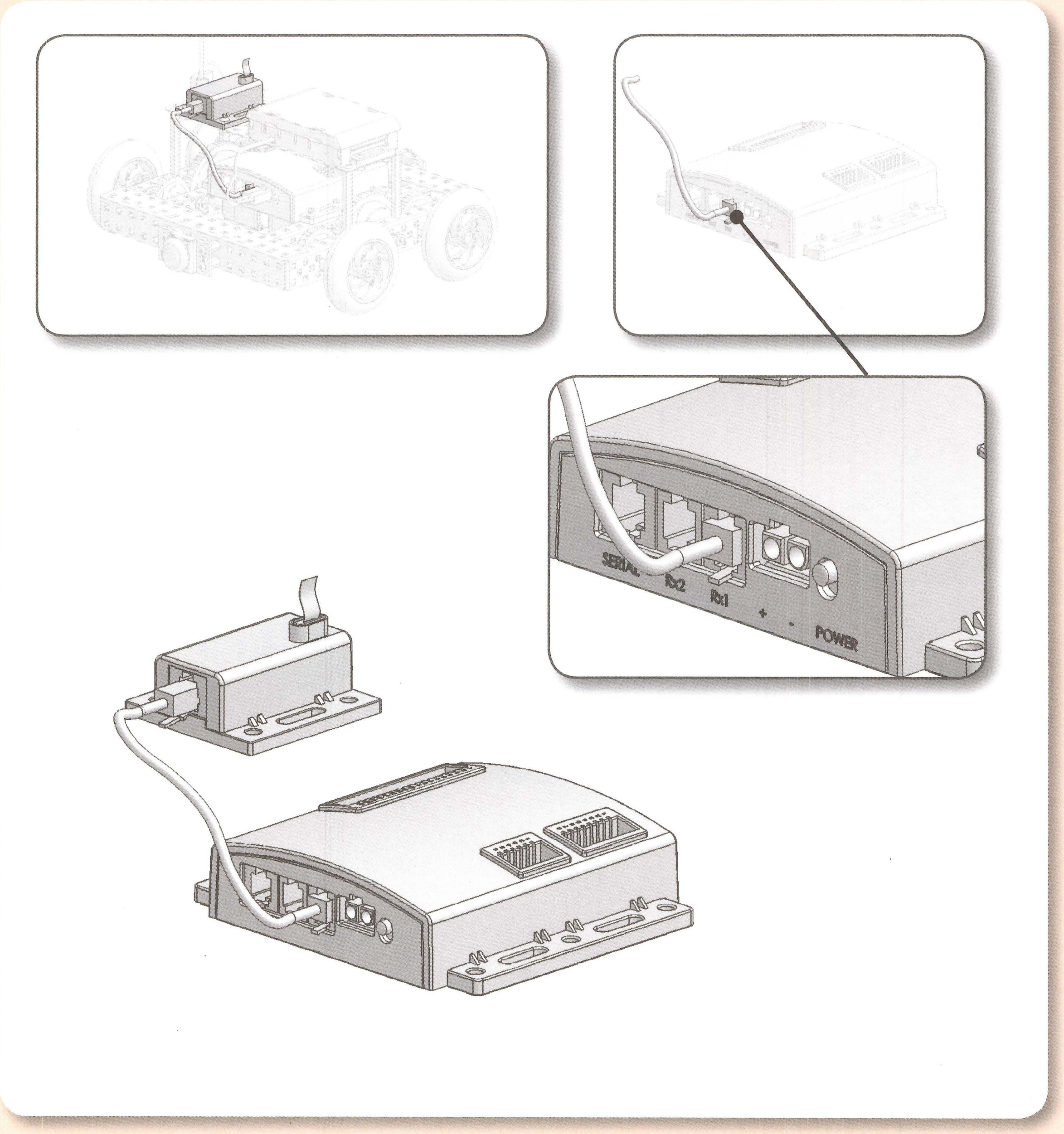


The Sensor Subsystem is now connected to the Logic Subsystem.

squarebot logic parts & assembly, continued

3 Connect components to the Micro Controller, continued

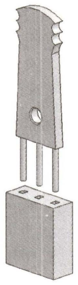
Connect the RF Receiver module into the rear of the Micro Controller. Take the 9″ RJ-10 wire and plug one end into the back of the RF Receiver Module. Plug the other end into the port marked "Rx1" on the rear of the Micro Controller.



The Control Subsystem is now connected to the Logic Subsystem.

logic subsystem

Jumpers

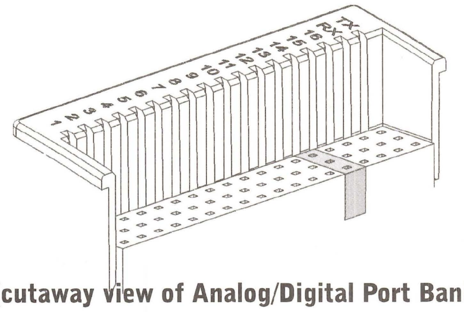


Jumpers are small plastic pieces with a metal connector inside them. When inserted into a port, a jumper completes an electrical connection between two of the metal contacts inside, like closing a switch in a circuit. The Vex jumper clips are 3 holes wide because they join the two outer contacts in the port and skip the middle one (they don't join all three, that would cause a short circuit).

Jumpers are most commonly used to set an option on the Robot Controller. Placing a jumper on a given Analog/Digital port will typically activate a certain behavior in the robot's programming (see Port Mappings later in this section).

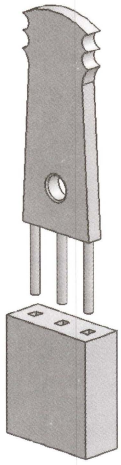
How to install a jumper

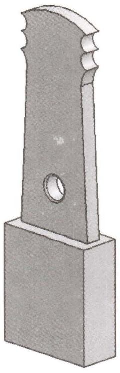
First, find the port you would like to place the jumper on. Remember that a port is a set of three holes running horizontally. A port bank (like the Analog/Digital Port Bank) consists of a collection of ports.



(cutaway view of Analog/Digital Port Bank)

Once you have found the port, all you need to do is insert the jumper so that the metal pins go into the three holes, and the jumper itself sits securely in position over the port.





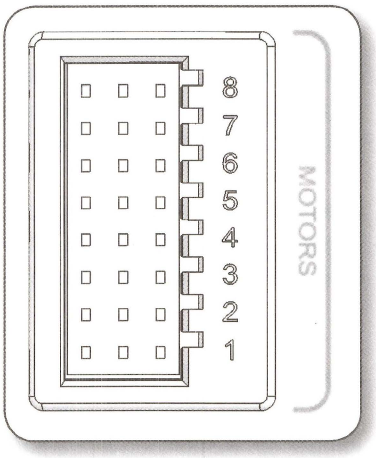
logic subsystem, continued

Port Mappings - Ports on top of the controller

Motors

These ports are for motors only. By default, your robot's left motor goes on Port 3, and your right motor goes on Port 2. However, there are a number of alternate control configurations available: see "Basic Controller Operation" in the Control Subsystem chapter for basic configurations, and "Advanced Operator Control Configurations" at the end of this chapter for more advanced options (including the 4WD mode mentioned in the chart below).

Shown here are the motor port allocations for the two "Basic" control layouts.

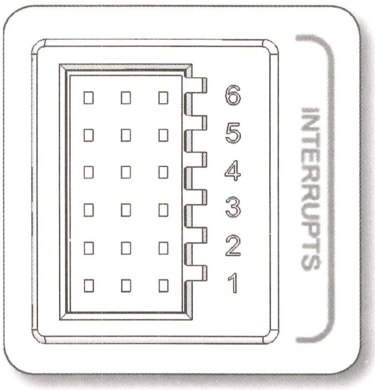


	DEFAULT "23 mode" Control Tank Style	**"12 mode" Control Arcade Style**
Motor Port 1	*	LEFT MOTOR
Motor Port 2	RIGHT MOTOR	RIGHT MOTOR
Motor Port 3	LEFT MOTOR	*
Motor Port 4	*	*
Motor Port 5	*	*
Motor Port 6	*	*
Motor Port 7	Right Rear Motor in 4WD mode *	Right Rear Motor in 4WD mode *
Motor Port 8	Left Rear Motor in 4WD mode *	Left Rear Motor in 4WD mode *

* The inventor may use these motor ports to control inventor designed accessories.

Interrupts:

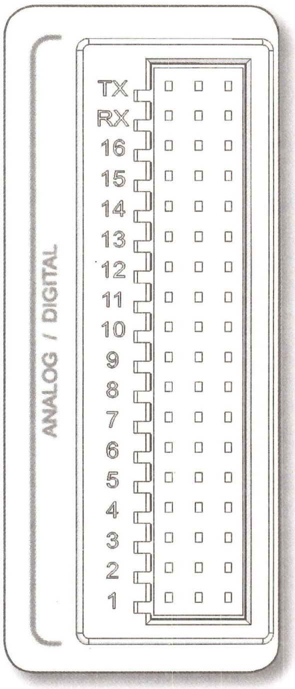
These ports are for advanced features that are not supported in the Starter Kit.



logic subsystem, continued

Digital/Analog Input Ports:

This is a bank of 16 multipurpose input/output ports. In the pre-programmed configuration, most of these ports (1-12) are used as sensor inputs, and have behaviors associated with them that are activated when a sensor is plugged in. The remainder are used to configure advanced settings on the controller by setting or removing jumpers.



Jumper Ports

Port	Function	For More Information
Jumper Port 16	"12 Mode" 4-Wheel Drive Enable/Disable	Advanced Operator Control Configurations section in this chapter
Jumper Port 15	"23 Mode" 4-Wheel Drive Enable/Disable	Advanced Operator Control Configurations section in this chapter
Jumper Port 14	"Software 12 mix Mode" Enable/Disable	Advanced Operator Control Configurations section in this chapter
Jumper Port 13	Autonomous Mode Enable/Disable	Autonomous Mode section in this chapter

Sensor Ports

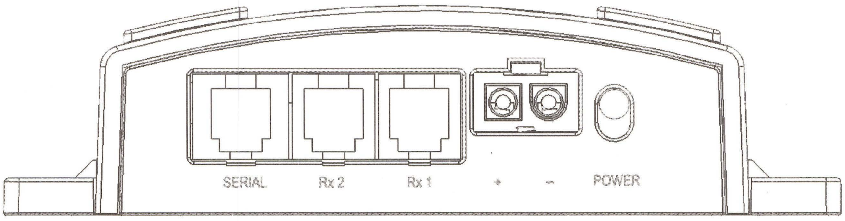
Port	Function	For More Information
Sensor Port 12	Autonomous Mode Collision Detection Sensor Ports	Autonomous Mode section in this chapter
Sensor Port 11		
Sensor Port 10	Tag or Collision Emergency Stop Ports	Sensor Subsystem Chapter
Sensor Port 9		
Sensor Port 8	Limit Switch Ports	Sensor Subsystem Chapter
Sensor Port 7		
Sensor Port 6		
Sensor Port 5		
Sensor Port 4		
Sensor Port 3		
Sensor Port 2		
Sensor Port 1		

TX/RX Ports

At the end of the Digital/Analog Port Bank are two ports marked TX and RX. These ports are for advanced features that are not supported in the Starter Kit.

logic subsystem, continued

Port Mappings - Ports on the back panel of the controller



Serial (Programming) Port
This port is for use with the Vex Programming Kit and is not used in the Starter Kit.

Rx1 and Rx2 (Radio Receiver) Ports
These ports are for radio receivers to communicate with the Micro Controller. The Vex Micro Controller supports up to two receivers simultaneously, allowing two operators to control different parts of the same robot at the same time. One operator will usually focus on maneuvering the robot, while the other operator runs the other onboard attachments and equipment.

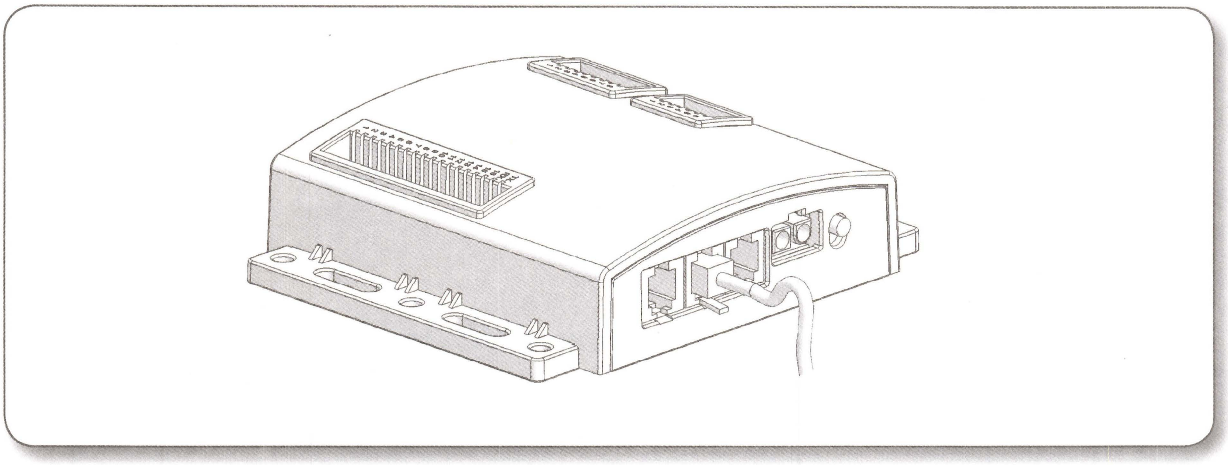
Rx1: Primary operator (driver) port
Rx2: Secondary operator port

(+ -) Battery Port
This is a standard connector for 7.2V power sources, such as the Battery Holder or the Vex Power Pack. It is "keyed" with an asymmetric plug shape to prevent accidental insertion in the wrong direction. The Micro Controller draws power for both its own operation and for all other attached devices through this port.

logic subsystem, continued

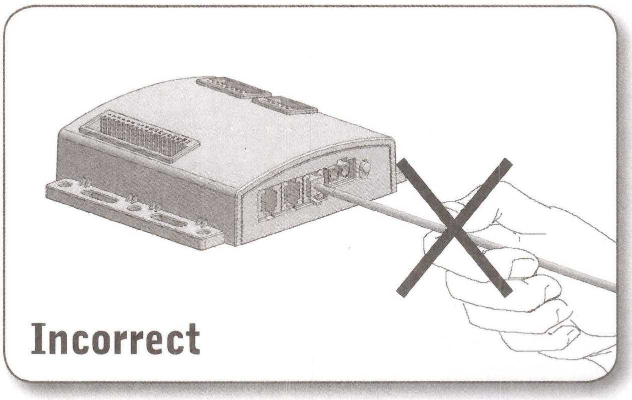
Wires and Connectors

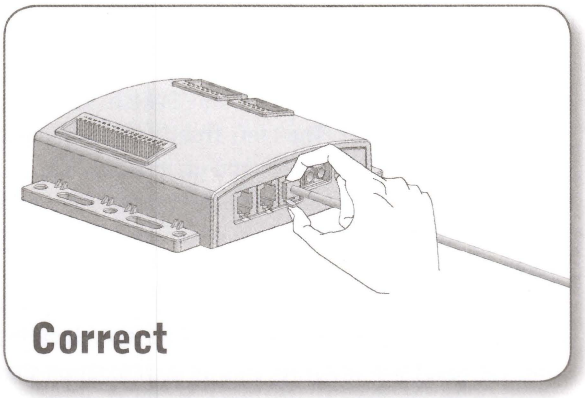
Be careful with wires. Not only are they crucial for your robot to work, but they are fragile and often messy to manage, and worse, they have a tendency to become exposed to environmental hazards (like other robots that can snag on them). Here are a few tips:



Tie your wires. The Vex Robotics Design System Starter Kit comes with lots of wire ties, so there is no excuse for not tying your wires down to keep them safe! Tie wires to parts of your robot that are far away from moving parts if possible, and try to keep them out of the way of areas where you will need to do maintenance work.

Don't pull wires. When removing a wire that is already plugged in, never pull on the wire itself. Always grip the connector head and pull. Never apply force to the wire, or it may become detached from the head.

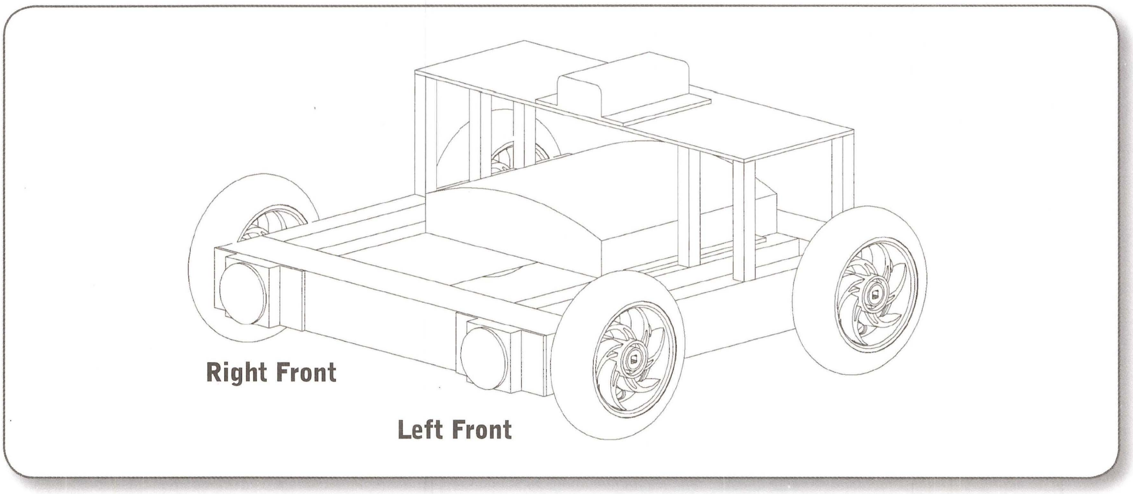

Incorrect


Correct

Don't force connectors. All the connector ports in the Vex Robotics Design System are "keyed", meaning that the plastic connectors are constructed so that they only fit in one direction. Do not force connectors in backwards! Not only will this physically damage the port and head, but you also risk electrical damage to the Micro Controller and the component you were trying to plug in.

logic subsystem, continued

Autonomous Mode



Port	What to plug in	Function
Analog/Digital 13	Jumper	Activates autonomous mode
Analog/Digital 11	Left-front Bumper Switch Sensor	Left side collision detector
Analog/Digital 12	Right-front Bumper Switch Sensor	Right side collision detector
Motor Port 3	Left Motor	Move robot according to commands issued by autonomous mode program
Motor Port 2	Right Motor	

Autonomous mode allows the robot to operate one very simple pre-programmed behavior without any human input. When enabled, the robot will wander around, using a pair of bumper or limit switch sensors to detect obstacles.

- You must enable Autonomous Mode in order to use the autonomous behavior. Place a Jumper Clip on Digital Input 13 to enable Autonomous Mode operation.
- Plug the Bumper Switch or Limit Switch Sensors into ports 11 and 12 to use this behavior. The "left-front" sensor should go into port 11, and the "right-front" sensor should go into port 12.
- The robot will begin running autonomously 2-3 seconds after being turned on. The delay is intended to give the person who turns it on some time to get out of its way.
- The robot will drive straight forward without human control when in Autonomous Mode. When the bumper switch on input port 11 is pushed in, the robot will interpret this as an indication that it has run into an immovable obstacle on the left side, and will turn to the right until the switch is no longer pushed in. The bumper switch on input port 12 does the same thing, but monitors the right side and makes the robot turn left when it is pushed.
- Human control is disabled! Be sure to watch the robot to ensure that it does not venture into any dangerous areas. In particular, the robot has no way of detecting "negative obstacles", like ditches or cliffs. Pick up the robot and stop it if it is in danger of damaging itself!

logic subsystem, continued

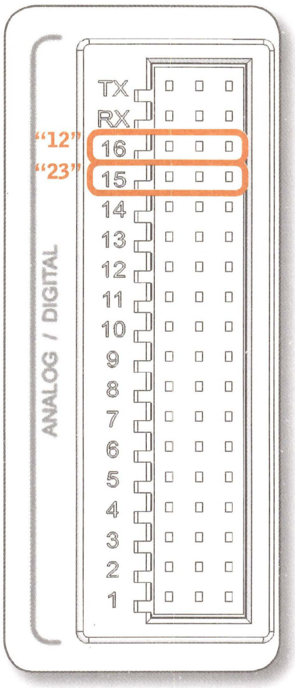
Advanced Operator Control Configurations

The descriptions below are summaries. You will find a complete listing of different control layouts in Appendix F.

4WD (Four Wheel Drive) Jumpers 15 and 16

Jumpers 15 and 16 are used to set the robot into four-wheel drive mode, which uses four motors to run a four-wheeled robot (instead of two motors like Squarebot). The two left wheels will always turn together, as will the two right wheels.

The rear-left motor should go on Motor Port 8, and the rear-right motor should go on Motor Port 7. If you are in "23 mode" on the Transmitter, you should then attach a jumper to Digital/Analog input port 15. If you are in "12 mode", put the jumper on port 16 instead. If you wish to use both 4WD and "Software 12 mix" mode (see below), you do not need either jumper 15 or 16, because the "Software 12 mix" automatically enables 4WD.

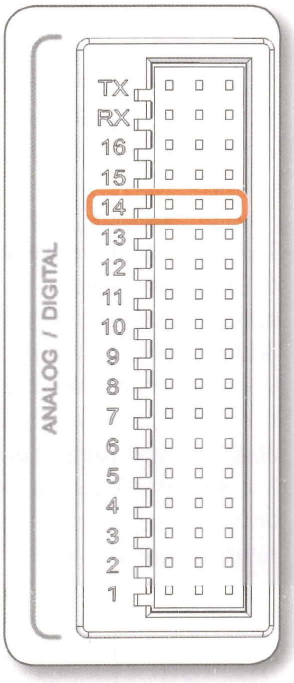


"Software 12 mix" Jumper 14

Placing a jumper on this port will activate programming on the Micro Controller that will allow it to behave as if you had activated the "12 mode" on the Transmitter (see Basic Controller Operation in the Sensor Subsystem chapter for more information on "12 mode" on the Transmitter). You must set the Transmitter itself to "23 mode" in order to use this feature otherwise your controls will not behave correctly (your input will be "mixed" twice, producing the wrong motor commands).

This version of the "12 mode" is slightly different from the Transmitter's "12 mode", however, because it will allow you to go at full speed straight forward, whereas the Transmitter's "12 mode" will only go 60% of full speed forward. The result is that the "Software 12 mix" mode goes faster, but feels like it slows down during turns; Transmitter "12 mix" mode will go slower, but feels more responsive in turns.

4WD is enabled automatically in "Software 12 mix" mode, so note that ports 7 and 8 will be treated as right-rear and left-rear wheel motors respectively; you can hook up additional motors to use 4WD, but you can't use these ports to independently control other attachments.



concepts to understand

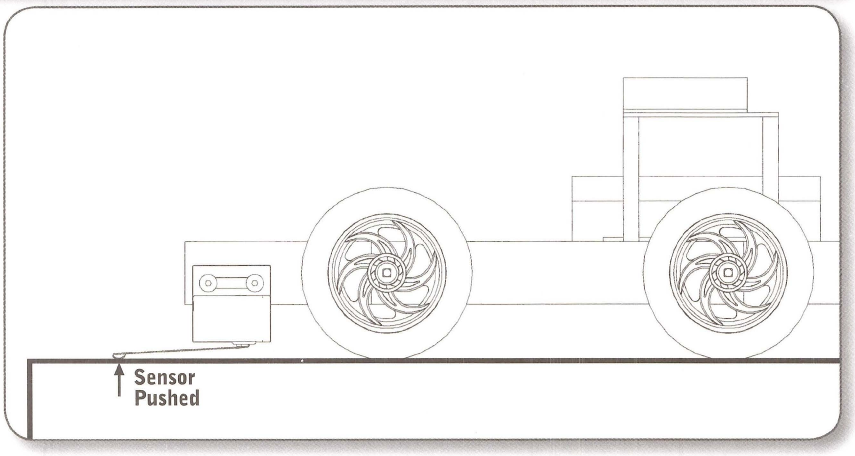
Role of Electronic Control

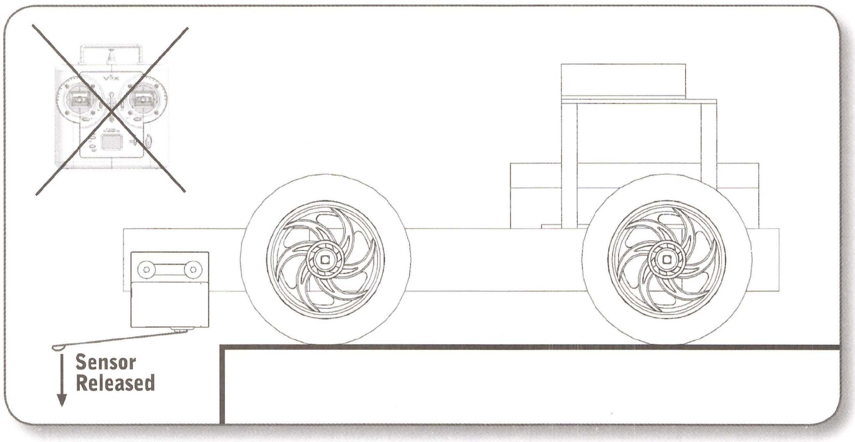
A robot is a very complex system of parts that must work together in order to achieve a desired goal. Electronic control provided by a programmable controller like the Vex Micro Controller allows the robot to coordinate the operation of the different components and achieve its goals.

Sensing, Planning, Acting: Cliffbot

Robots characteristically have two major capabilities that other mechanical systems don't have: they can sense important things about the world around them through the use of sensors, and they can process sensor information according to a pre-programmed routine. They then act on that plan, by directing motors and other output devices.

For instance, consider the robot to the right, which has been programmed to respond to radio control commands from a human operator so it can be driven just like a normal radio controlled car, except that the robot is also equipped with a "cliff detector" sensor attachment. The robot will drive around as directed, unless the sensor detects that the robot is about to run off a cliff. Upon detecting a cliff hazard, the robot would temporarily disable human control, give a visible signal to warn the driver of the danger, and then return control to the human operator, who can then maneuver safely away from the cliff (or keep going, if the robot was mistaken).

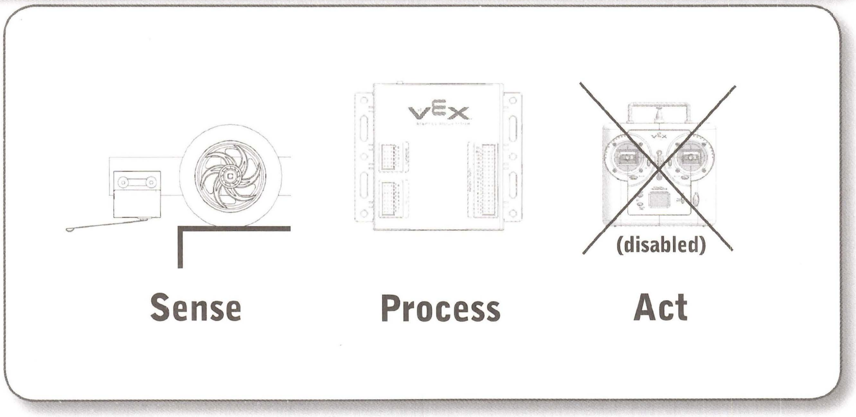




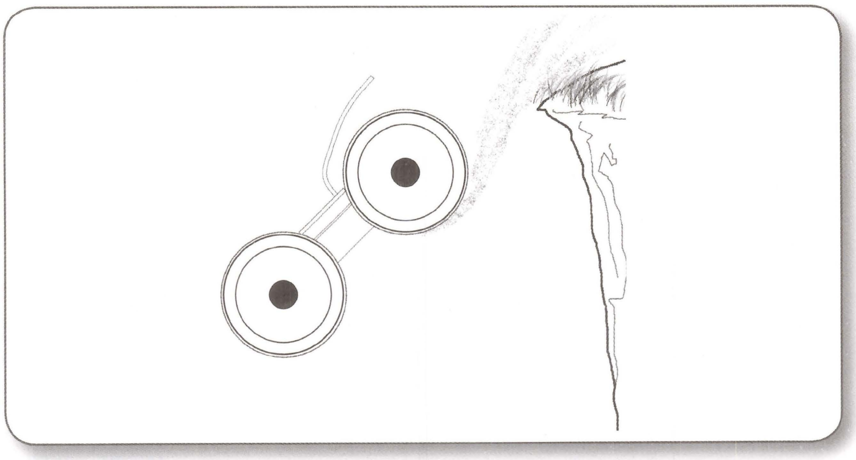
concepts to understand, continued

Sensing, Planning, Acting: Cliffbot, continued

In order to accomplish this, the robot needs to be able to sense the presence of a cliff hazard through the "cliff detector" sensor. The robot then processes its course of action the robot doesn't detect a cliff, then it obeys the human controller's input, but if the robot detects a cliff, it will instead automatically stop and alert the driver.



In contrast, a simple radio controlled car would not have this capability. Without the ability to sense, or to react based on sensor feedback, the car would have no way to do anything but blindly follow the commands of a human controller who might not be able to see very well from where he or she is standing...



subsystem interactions

How does the Logic Subsystem interact with...

...the Structure Subsystem?

- The structure subsystem holds the Micro Controller in place. Since the Micro Controller is a very delicate and important part of the robot, the structure subsystem will also need to provide physical protection for the Micro Controller by keeping it in a secure spot.
- The structure subsystem does not plug into the Micro Controller in any way; however, the structure subsystem does need to provide accommodation and protection for the wires that run between the Micro Controller and other pieces.
- On the Squarebot, the structure subsystem provides a mounting platform for the controller module, and a place to tie wires down.

...the Motion Subsystem?

- The Logic Subsystem provides power and issues output commands to the Motion Subsystem components. Though these commands are usually based on user input (relayed through the Control Subsystem), the final decision on what command is issued, as well as the actual flow of electricity (from the Power Subsystem) is all controlled the Logic Subsystem.
- Motors from the Motion Subsystem plug into the Motors port bank on the top of the Micro Controller.
- The two motors on the Squarebot plug into Motor Ports 2 (right motor) and 3 (left motor) in the default control layout.

...the Sensor Subsystem?

- The Logic Subsystem relies on feedback from the Sensor Subsystem to provide information about the robot's environment. It uses this data to make informed decisions about how the robot should behave.
- The actual behavior that is activated when a sensor is triggered depends on which port the sensor is plugged into on the Micro Controller.
- The Squarebot has two bumper sensors, one for the front and one for the rear. These are plugged into the "Tag" behavior ports to function in either the Tag game or as an emergency stop mechanism.

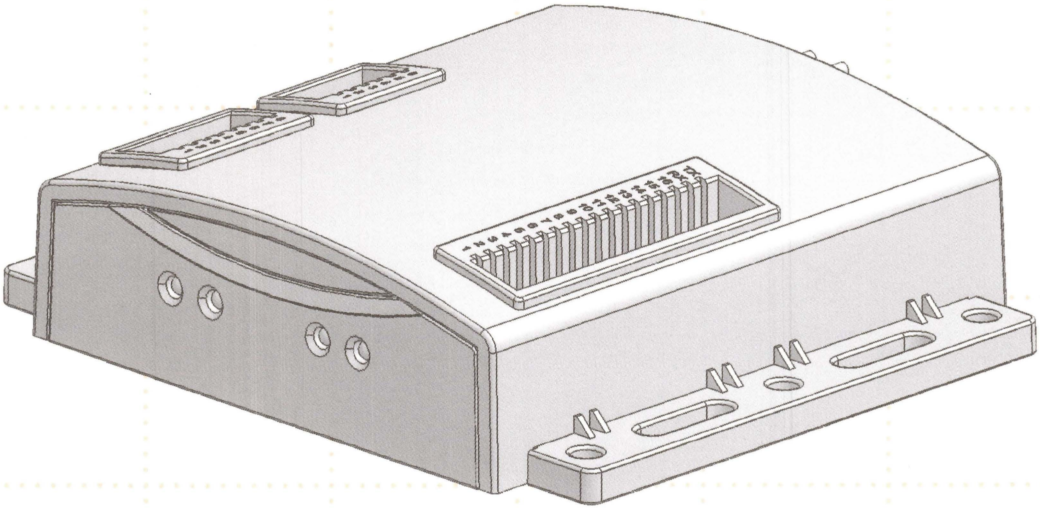
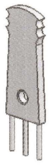
...the Control Subsystem?

- The Micro Controller module controls the flow of commands from the human operator to the robot. The Micro Controller ultimately decides whether to pass joystick commands on to the motors, to modify them, or to override them, based on its programmed behavior and other information available to it (from sensors, for instance).
- The RF Receiver Module is connected to the Vex Micro Controller through the 9" RJ-10 cable that runs from the back of the Receiver into the front of the Micro Controller. Up to two Receivers can be supported simultaneously.
- If desired, the Transmitter can be hooked directly into the Vex Micro Controller using a tether cable, bypassing the RF Reciever Module (see the Control Subsystem chapter for details).
- The specific way that the robot will respond to joystick movement is determined by a combination of Transmitter and Micro Controller settings. See Appendix F for a full listing of control layouts.
- The Squarebot receives user driving commands through the the RF Receiver Module and uses the default control layout.

... the Power Subsystem?

- Since the Micro Controller is device that contains a large number of electronic components, including two computer processors, it needs power, which it draws directly from its connection to the Power Subsystem.
- The Micro controller redistributes electrical energy from the Power Subsystem batteries to the other subsystems' components (like motors).
- The Power Subsystem battery holder (or battery pack) connects to the Micro Controller module using a two-pin connector inside a plastic housing, which is mechanically keyed to prevent it from being plugged in backward. The port is on the rear of the Micro Controller next to the power switch.

logic & control subsystem inventory

component	qty
controller 	1
jumper clips 	5

reference

safety considerations

General Safety Guidelines

- **Always wear safety glasses** to protect your eyes. Note that normal glasses, while usually made of impact-resistant plastic, will not afford sufficient protection from shrapnel or flying debris.

- **Always wear close-toed shoes** to protect your feet from heavy or sharp objects which might be dropped.

- **Avoid wearing loose-fitting clothing** which can become caught in moving parts of the robot or of whatever machinery you may need to use during the construction of the robot.

- **If you have long hair,** keep it tied back or under a hat to avoid it becoming caught in moving parts.

- **Do not wear gloves when operating machinery** (e.g. drill press or belt grinder), as glove may become snagged and drag your hand into the machinery.

- **The kit contains small parts.** Do not ingest. Do not insert into any orifice (e.g. nostrils).

- **NO HORSEPLAY.**

safety considerations, continued

Subsystem-Specific Safety Guidelines

- **Structure**
  - **Contains metal parts.**

    Cutting or excessive bending can cause parts to break, resulting in sharp edges which can cut skin.

- **Motion**

  When system is powered, keep fingers, tools, hair, and all other body parts away from gears, wheels, etc. Plastic parts can still painfully pinch, cut, or crush.

- **Power**
  - **Battery use**

    Do not lick batteries.

    If battery appears to be leaking or has a crystalline deposit on the outside, dispose of it immediately (do wear gloves when handling, preferably nitrile or other non-reactive material).

    Do not run a wire from one end of battery to the other, as wire will get very hot.

  - **Battery disposal**

    Do not throw batteries into the trash, especially rechargeable batteries.

    Contact your local waste disposal office for information on battery disposal. Batteries should be stored as directed by your local hazardous materials disposal office until pickup (usually in a hard-sided, waterproof, non-conductive container, e.g. a plastic bucket).

- **Logic**

  Contains small parts. Do not ingest or insert into nostrils, ears, etc.

- **Sensors**

  Contains small parts. Do not ingest or insert into nostrils, ears, etc.

- **Radio**
  - Batteries: see Power section
  - Mechanical: do not insert antenna into any orifice

glossary

#

12 mode – Control Subsystem
A Transmitter driving mode where axes 1 and 2 are used to control the primary navigation of the robot. Also called Arcade-style controls.

23 mode – Control Subsystem
A Transmitter driving mode where axes 2 and 3 are used to control the primary navigation of the robot. Also called Tank-style controls.

4WD – General
Short for Four-Wheel Drive. A four-wheel drive robot typically has four wheels, all of which are powered independently. This usage is analogous, but not identical, to the meaning of the term with respect to automobiles.

a

Acceleration – Motion Subsystem
In physics, acceleration is the change in velocity of an object over time. In robotics, acceleration usually refers to the ability of a robot to speed up or slow down quickly on demand.

Alkaline (Battery) – Power Subsystem
A class of battery chemistries commonly used in disposable batteries. This type of battery is not suited for use in robotics applications.

Allen Wrench - General
An L-shaped tool used to work with hex screws.

Analog Sensor – Sensor Subsystem
Analog sensors communicate with the Micro Controller by setting an electrical voltage in the system to a value between 0 and the maximum voltage.

Analog/Digital Port Bank – Logic Subsystem
A group of ports on the Micro Controller used for analog and digital communication with other parts of the robot system. In the Starter Kit, most of the ports are used as sensor inputs, some are used for jumper settings, and a few are unused.

Arcade-style Controls – Control Subsystem
A Transmitter driving mode in which the robot is controlled with one joystick on the Transmitter, like an arcade game. Also called 12 mode because axes 1 and 2 are being used to drive the robot.

Attachment – Structure Subsystem
Generally, any piece that is "attached" and not fundamentally part of the basic robot design. Usually refers to such pieces as arms or sensor modules, especially if they are removable.

Autonomous – Logic Subsystem
Technically, a robot must be able to function entirely without human supervision to be considered fully autonomous. Almost all real-world robot systems are designed instead to work with partial autonomy under varying degrees of human supervision.

Autonomous Mode – Logic Subsystem
The Vex robot has a simple pre-programmed autonomous mode that uses two bumper or limit switch sensors to detect obstacles as the robot wanders around a room or course.

Axis (Joystick) – Control Subsystem
One of two axes (X and Y) along which a Transmitter joystick can move. Each axis on the joystick is associated with an onboard potentiometer that measures the joystick's position along that axis.

Axis of Rotation – Motion Subsystem
The imaginary line around which a spinning object rotates. This usually coincides with the axle for a wheel or gear.

Axle – Motion Subsystem
A long, rigid piece through the rotational center of an object (like a gear or wheel). Axles serve two main purposes: to hold spinning bodies in place relative to the rest of the structure, and to transfer rotational motion from one spinning piece to another (as in the case of a motor axle turning a gear). Square bars are usually used as axles in the Vex system.

glossary

b

Back-driving – Motion Subsystem
A damaging condition where a motor is engaged in one direction, then made to spin in the opposite direction by force. This condition can be avoided through the use of a clutch, which will disengage the motor when too much backwards-spinning force is encountered.

Battery – Power Subsystem
Normally, any portable power source, such as the Vex Power Pack battery. Technically, a battery is a collection of multiple cells, but single cells are often referred to as batteries in common usage.

Battery Holder – Power Subsystem
The Vex Starter Kit uses the Battery Holder to create a 7.2V battery out of 6 1.2V AA cells (by connecting them in series). The Battery Holder also holds the AA cells in place on board the robot.

Bearing – Structure Subsystem
A piece that is used to hold a moving piece (such as an axle) in place relative to the rest of the system.

Bearing Flat – Motion Subsystem
A commonly used type of bearing in the Vex system. This bearing has three holes in a row. The bearing is secured to the chassis with screws through two of the holes, and an axle is passed through the third, which allows it to spin freely but not move out of place relative to the chassis.

Behavior – Sensor Subsystem, Logic Subsystem
In the context of robotics, a behavior is the pattern of actions a robot will enact when given certain inputs or commands.

Bumper Switch Sensor – Sensor Subsystem
A high-durability sensor designed to detect physical contact. This is a digital sensor.

c

Calibrate (Sensor) – Sensor Subsystem
Calibrating a sensor is the process of matching sensor readings against known values to ensure that the sensor input is being interpreted correctly in the program. Simple sensors, like the Bumper and Limit Switches, typically do not need to be calibrated.

Calibrate (Joysticks) – Control Subsystem
Calibrating the transmitter joysticks (also called "trimming" the sticks) is the process of adjusting trim values on the Transmitter to ensure that the sticks produce no motor movement when they are centered. A more thorough calibration process also includes setting the scaling and end points to ensure a full range of motion.

Carrier Wave – Control Subsystem
The carrier wave for FM communication is a simple sine wave with a set frequency. It is then modified (modulated) by the addition of the desired signal wave to produce the final output wave that is sent to the receiver.

Caster Wheel – Motion Subsystem
A free-swiveling wheel mounted on a robot to provide stability while producing a minimum of friction. The front wheels on a shopping cart are caster wheels; they support weight and stabilize the cart, but do not add significant amounts of friction like a skid would, nor do they change the maneuvering characteristics of the cart like an additional locked wheel would.

CCW – General
Short for Counterclockwise.

Cell – Power Subsystem
A single electrochemical unit producing a known voltage differential, such as a single NiCd AA battery, which has a voltage of 1.2V between the + and - terminals.

glossary

Center of Gravity – Structure Subsystem
The robot's center of gravity is the average position of all the mass on the robot (technically, this is the center of mass, but under terrestrial gravity conditions, they are the same). It is critical that the center of gravity be kept directly over the support polygon, or the robot will fall over.

Challenge – Vex System
Vex Challenges are designed to give you a specific task to accomplish by building a robot, and to open possibilities for collaboration and competition with other robot designers.

Chassis – Structure Subsystem, Motion Subsystem
A vehicle's basic structural frame, plus its locomotion systems. In the Vex system, this is generally the Structure Subsystem plus the Motion Subsystem, minus any attachments.

Circumference – General
The distance around the edge of a circle. This quantity is equal to pi times the circle's diameter, or 2 times pi times the radius.

Clockwise – General
A rotational "direction" that prescribes turning in the same direction as the hands on a clock normally turn.

Clutch – Motion Subsystem
A detachable piece normally mounted to the Vex motors that prevents them from entering the potentially damaging stall or back-driving conditions. These should not be removed under most circumstances.

Collar – Structure Subsystem
A type of spacer that can be set to remain stationary at any given point along an axle. These are often used to keep other components on the axle (or sometimes the axle itself) from sliding out of position.

Compound Gear – Motion Subsystem
A system of gears involving several pairs of gears, some of which share axles with each other. When calculating gear ratio, this whole system of gears behaves as if it were a single gear pair with a gear ratio that might not otherwise be achievable.

Compound Gear Ratio – Motion Subsystem
The overall equivalent gear ratio produced by a group of gears in a compound gear configuration. This can often be quite high or quite low, due to the multiplicative nature of gear ratios in a compound gear system.

Configuration (Transmitter) – Control Subsystem
One of the 5 different control setups stored on the RF Transmitter. Each configuration saves the Transmitter menu settings that were set while using that configuration number.

Control Subsystem
The subsystem responsible for collecting human operator input and communicating it to the Micro Controller.

Control Channel – Control Subsystem
One of the 6 pathways for control information traveling from the Transmitter to the Micro Controller. The X-axis of the right joystick, for instance, sends its data over control channel 1 (that axis of the stick itself is sometimes referred to as Channel 1 as a result). Note that control channels are not the same as radio channels.

Counterclockwise – General
A rotational "direction" that prescribes turning in the opposite direction from the way the hands on a clock normally turn.

Crystal (Radio Frequency) – Control Subsystem
One (or sometimes both) of the crystals that determine the frequency on which the Transmitter and Receiver operate. The crystal used in the Transmitter Frequency Module must match the crystal used in the Receiver for controls to be sent and received properly.

CW – General
Short for Clockwise.

glossary

d

Deep Cycling – Power Subsystem
Draining a battery down to very low power (below the normal cutoff levels) before recharging it. This will wear a rechargeable battery out very quickly, and should be avoided if possible.

Diameter – General
The distance from one point on a circle to the point directly across from it. This quantity is equal to two times the radius, or it can be multiplied by pi to find the circumference of the circle.

Digital Sensor – Sensor Subsystem
Digital sensors communicate with the Micro Controller by setting an electrical voltage in the system to one of two values: either a digital LOW equal to 0V, or a digital HIGH equal to the maximum voltage on that port.

Discharge Cycle – Power Subsystem
Technically, any period during which power is drawn from the battery and then recharged. Usually used in one of two contexts: either when referring to the usage pattern of a battery (using a battery for a short time, then recharging it constitutes a pattern of short discharge cycles), or when battery chargers automatically drain the battery before recharging it (the charger performs a "discharge cycle" on the battery).

Drive Train – Motion Subsystem
All the parts involved in the primary locomotion system of a robot, including the motors, gears, axles, and wheels.

Driven Gear – Motion Subsystem
In a gear train, the last gear being turned. Usually, this gear shares an axle with a wheel.

Driving Gear – Motion Subsystem
In a gear train, the gear that provides the energy to turn all the other gears and their connected components. This gear usually shares an axle with a motor.

Driving Mode (Transmitter) – Control Subsystem
The driving mode selected on the Transmitter through the DRIVE menu, either "23 mode" or "12 mode." This setting (together with Jumper 14 on the Micro Controller) determines which combination of joystick axes on the Transmitter will control the robot's movement.

e

Electromagnetic Waves – Control Subsystem
Technically, a time-varying electric field that propagates through space at the speed of light, caused by the acceleration of a charged particle. More simply, an electronically controllable wave that travels at the speed of light and can carry information between two points through a variety of encoding techniques.

End Points (Joystick) – Control Subsystem
End points control the percentage of the full power command that will be sent by the Transmitter when the joystick is pushed to the edge of its movement area.

Exponential Scaling – Control Subsystem
A control scaling method that allows for "stiffening" or "softening" of the feel of the joystick controls by causing the output command value to increase faster or slower than it normally would as the joystick is moved away from the center of its movement area.

f

Fastener – Structure Subsystem
A general term for pieces (such as screws) whose primary purpose is to hold two or more other components together.

Floating – Structure Subsystem
As opposed to "locked." Moving freely, not held in one specific place. A collar floats freely on a square bar when the screw is not tightened (it slides easily up or down the bar).

Flush – Structure Subsystem
As in "flush against another part." Pushed up against something, leaving no space between them. A collar is flush against a bearing when it is pushed up against the bearing as far as it can go.

glossary

Four Wheel Drive – Control Subsystem
A four-wheel drive robot typically has four wheels, all of which are powered independently. This usage is analogous, but not identical, to the meaning of the term with respect to automobiles.

Frequency-Modulated Signals – Control Subsystem
Frequency-Modulated (FM) signals are used in the Vex system to encode data in radio transmissions. Radio waves are a form of electromagnetic wave with a very high frequency. The frequencies used by the Vex system all have a carrier frequency near 75MHz, which is part of the VHF (Very High Frequency) band of the electromagnetic spectrum. This carrier wave is then modulated by the signal wave by adding together their frequencies at every point in time to produce a third wave, which is transmitted through the air and received by the RF Receiver Module on the robot.

Friction – Motion Subsystem
The force between two objects moving at different speeds that acts to slow their movement relative to each other. In robotics, this usually has one of three contexts: friction between wheels and ground that results in rolling wheels slowing down, friction between wheels and ground that allows wheels to "push off" and start moving to begin with (rather than spinning in place), and friction between any two components rubbing together in the robot that result in loss of energy.

g

Gear – Motion Subsystem
Essentially, gears are spinning discs with teeth that prevent them from slipping past each other. Gears are frequently used to transfer rotational motion from one piece to another, and to provide mechanical advantage while doing so. The number of teeth on a gear (assuming the same spacing between teeth on both gears, so their teeth mesh properly) is directly proportional to the gear disc's circumference, thus the number of teeth can easily be used to calculate the gear ratios of gear trains.

Gear Ratio – Motion Subsystem
The mechanical advantage, or "force multiplier" generated by a group of 2 or more gears turning together. For simple non-compound gear trains, this can be calculated as the number of teeth on the driven gear divided by the number of teeth on the driving gear.

Gear Train – Motion Subsystem
In general, a group of gears that turn together to transmit motion from one point to another on the robot, often providing mechanical advantage along the way.

Gripper – General
An attachment designed to pick up or hold an object, often by "gripping" it with claw-like appendages.

Gusset – Structure Subsystem
A piece used to strengthen an angled joint. There are two kinds of gussets in the Vex Starter Kit.

h

HIGH (Digital value) – Sensor Subsystem
One of two possible values in a digital system (the other is LOW). The voltage used to indicate HIGH usually corresponds to the maximum voltage of the system.

Hub – Motion Subsystem
With wheels, the hub is the center portion of the wheel that joins to the axle. Note that the grey hub in the center of the 2.75" small wheel in the Vex Starter Kit can also be used as a wheel by itself (without the green rubber tire portion), but this is not the norm.

i

Idler Gear – Motion Subsystem
A gear in a gear train that is neither the driven nor the driving gear, and does not share an axle with another gear in the train (i.e. does not form a compound gear). Each idler gear in the train reverses the direction of spin once, but never affects the gear ratio.

glossary

Interrupt Port Bank – Logic Subsystem
A port bank on the Micro Controller used primarily for advanced programming functions. These ports are not used in the Starter Kit.

i

Jumper – Control Subsystem, Logic Subsystem
A metal wire contained in a plastic housing that can be placed (and removed) by hand to complete (break) an electrical connection. These are most often used to "set" options on the Micro Controller by placing them in ports in the Analog/Digital Port Bank. Placing a jumper in one of these ports closes a circuit, setting the voltage for that port's input value, much like closing a limit switch sensor would.

k

Keps Nut – Structure Subsystem
A variant of the standard nut that includes a toothed "crown" designed to bite into a mounting surface and prevent the nut from slipping. Nuts are used to allow a screw to function as a fastener when the actual component being fastened does not include its own threading.

Keying (connectors) – Logic Subsystem
An intentionally asymmetrical construction of a connector to prevent backwards insertion. The power port on the Vex Micro Controller is keyed (the two plastic shapes in the middle are not the same), for instance, so that the power plug cannot be inserted upside-down.

l

Lever – Structure Subsystem
One of the simple machines that provides a mechanical advantage. There are three main classes of levers with subtle differences, but in general, long pieces that rotate around any point on their length will function as levers and can provide mechanical advantage.

Limit Switch Sensor – Sensor Subsystem
A small, contact-sensitive sensor that is most often used for internal regulation of movement, and should not be exposed to high-impact conditions. This is a digital sensor.

Linear Scaling – Control Subsystem
A control scaling method that allows for control of the overall range of motion and sensitivity of the joysticks on the Transmitter.

Logic Subsystem
The subsystem responsible for onboard robot operation, allocation of power, processing sensor feedback, and interpretation of human operator control.

LOW (Digital value) – Sensor Subsystem
One of two possible values in a digital system (the other is HIGH). The voltage used to indicate LOW usually corresponds to the zero (ground) voltage of the system.

m

Master Channel – Control Subsystem
In a Programmable Mix, the Master Channel is the control channel that, when manipulated by the operator, will also affect the value on the designed slave channel.

Mechanical Advantage –
Structure Subsystem, Motion Subsystem
The ratio of the force a machine can exert to the amount of force that is put in. Mechanical advantage can also be thought of as the "force multiplier" factor that a mechanical system provides.

If a vehicle has a gear train with a mechanical advantage of 2, for instance, it has twice as much force available to it, enabling it to go up hills that are twice as steep, or tow a load that is twice as heavy.

This additional force is never "free." It always comes at the expense of something else, such as speed. Also note that mechanical advantages are frequently fractional, indicating that force is being sacrificed for speed or some other similar performance factor in a system.

glossary

Memory Effect – Power Subsystem
Technically, the phenomenon where a rechargeable battery that is repeatedly discharged to the exact same level and then recharged will develop a permanently diminished capacity. True memory effect is observed only under laboratory conditions and on board solar-powered satellites in space. The more common usage of the term is incorrect, and is frequently used mistakenly to refer to voltage drop.

Micro Controller – Logic Subsystem
The "brain" of the robot. The Micro Controller contains the robot's program and processes all signals received from both human operators and onboard sensor systems. It also manages power allocation on board the robot, and directly controls the motors.

Miscalibrated – Control Subsystem
A condition where two values which should be the same do not, in fact, match each other. This occurs frequently with the joysticks on the Transmitter, which should produce a neutral motor state when centered, but will often cause motors to turn slowly instead when the sticks are released. Sensors that indicate things like distances can also become miscalibrated, and report values that do not reflect the actual physical situation.

Mix (Transmitter) – Control Subsystem
A control setup where inputting commands on one control channel influences the commands being sent on other control channels.

Motion Subsystem
The subsystem responsible for the generation and transmission of physical motion on the robot. This includes motors, gears, wheels, and many others.

Motor (Electric) – Motion Subsystem
An electromechanical device that converts electrical energy into kinetic (physical) energy on demand. The motion generated by a motor is almost always rotational in nature, and may need to be converted before it can be used to produce the desired effect.

Motor Port Bank – Logic Subsystem
The port bank on the Micro Controller where the motors are plugged in. The motors receive both commands and power through these ports.

Motor Shaft - Structure Subsystem, Motion Subsystem
A carried-over term from automotive engineering, this usually refers to the axle (square bar) that is directly driven by the motor.

Mounting Point – Structure Subsystem
Any place where a component can be conveniently attached. An open spot on the front bumper, for instance, may serve as a good mounting point for a forward-facing sensor.

n

NiCd (Nickel-Cadmium) - Power Subsystem
The preferred battery chemistry for the Vex Robotics Design System for performance reasons. A NiCd (pronounced Nai-kad) battery is an electrochemical cell which uses Nickel metal as its cathode material, and Cadmium metal as its anode material. Cadmium is highly toxic, and should not be disposed of in the trash.

Nut – Structure Subsystem
Nuts are used to allow a screw to function as a fastener when the actual component being fastened does not include its own threading. A screw and a nut "sandwich" the parts that are being fastened, and hold them together. The nut provides threading for the screw to lock into when none is present otherwise.

o

Overcharging – Power Subsystem
Continuing to apply a charging voltage to the battery after it has reached full capacity. This is very likely to damage your battery, and can be dangerous, as the battery will heat up rapidly while being overcharged, and may even explode if it gets too hot. Be sure your charger has the appropriate safeguards so that it will not attempt to overcharge your batteries.

glossary

p

Parallel (Batteries) – Power Subsystem
A battery arrangement where multiple battery cells are hooked up so that they provide the same voltage as a single cell, but drain power evenly across all the cells, thus behaving similarly to a single cell with a very large capacity.

Pivot – Structure Subsystem
A structural component that provides a mounting point for another component, but rather than locking it in place, the pivot allows the attached component to swivel or turn along a specific arc.

Power Subsystem
The subsystem responsible for storing and delivering electrical energy to the robot systems.

Programmable Mix – Control Subsystem
A feature of the Transmitter that allows the operator to designate one master channel and one slave channel to be used in a configurable control mix.

r

Radio Channel - Control Subsystem
A shortened name for a radio frequency. Radio frequencies often have long names, so they are given "channel" designations to be used as shorthand. 75.410MHz, for instance, is referred to as Channel 61.

Radio Frequency – Control Subsystem
A designated carrier frequency for radio transmission. Each transmitter-receiver pair should operate on a different radio frequency, and hence transmit data that will not interfere with other signals in the air. The radio frequency for a transmitter-receiver pair is determined by the frequency crystals installed in both devices.

Radius – General
The distance from the center of a circle to the edge. This quantity is equal to half the diameter, or it can be multiplied by two times pi to find the circumference of the circle.

RBRC – Power Subsystem
Rechargeable Battery Recycling Corporation.
A non-profit organization that facilitates the collection of rechargeable batteries for recycling, because rechargeable battery chemicals (such as the cadmium in NiCd batteries) tend to be very harmful to the environment when thrown in the trash.
http://www.rbrc.org

RF Receiver Module – Control Subsystem
The Control Subsystem component that receives and decodes FM radio signals that are sent by the Transmitter. After decoding the signals, they are passed on to the Micro Controller.

RF – Control Subsystem
Short for Radio Frequency, but often used to refer to any system or component that deals with radio transmission in any way (e.g. RF Receiver).

s

Screw, Hex – Structure Subsystem
A screw with a hexagon-shaped hole in the head, allowing the screw to be tightened or loosened with a hex L wrench.

Sensor Subsystem
The "eyes and ears" of the robot.
Electromechanical devices that can detect specific things about the robot and its environment, and communicate that information to the Micro Controller through an electrical signal.

Series (Batteries) – Power Subsystem
A battery arrangement where multiple battery cells are hooked up so that their voltages are added together, thus behaving similarly to a single battery with a much higher voltage.

Servomotor – Motion Subsystem
An electromechanical device that converts electrical energy into kinetic (physical) energy on demand. The difference between a standard motor and a servomotor is the way they respond to joystick commands. A motor will spin continuously in one direction or the other, whereas a servomotor will turn to face a specific direction within a limited arc.

glossary

Signal Wave - Control Subsystem
In radio transmission, the signal wave represents the data that is being sent, converted into a wave form in order to be included in an FM transmission.

Skid – Motion Subsystem
A non-wheel piece which rests on the ground and provides support for the robot, but is intended to slide when the robot moves. Skids provide support and stability without fundamentally altering the way the robot maneuvers, but they can cause significant friction, and often wear out quickly. Caster wheels are the preferred alternative in most cases.

Slave Channel - Control Subsystem
In a Programmable Mix, the Slave Channel is the control channel that is partly or completely controlled by the Master Channel.

Software 12 Mix - Control Subsystem, Logic Subsystem
A version of the "12 mix" arcade style controls where the control mixing takes place in software on the Micro Controller, rather than in hardware on the Transmitter. The software implementation of the controls also performs a few of the calculation differently, resulting in a somewhat different feel for the driver. This mode is activated by placing a jumper clip on top of Analog/Digital Port 14 on the Micro Controller.

Spacer - Structure Subsystem, Motion Subsystem
In the Vex Starter Kit, there are several green plastic spacers which are designed to slide onto square bar axles between other parts (or between parts and rails) to keep them from moving too close together. They can also be used like collars if enough spacers are added to keep the other parts from moving at all.

SPDT switch – Sensor Subsystem
Short for "Single Pull, Double Throw." A switch that is activated by a single contact (single pull), but changes the state of two outputs at once (double throw). The Limit Switch Sensor is an SPDT switch, but one of the two outputs is hidden, making it function effectively as an SPST switch.

Speed – Motion Subsystem
Technically, speed is the magnitude of velocity (i.e. velocity, but without indicating direction). It is most commonly used to mean the rate of movement of a vehicle. By extension, it can also mean the rate of rotation of a gear or wheel. It is also sometimes used to refer to a vehicle's potential maximum speed, as opposed to its acceleration capability.

SPST switch - Sensor Subsystem
Short for "Single Pull, Single Throw." A switch that is activated by a single contact (single pull) and changes the state of a single output (single throw). The Bumper Switch Sensor is an SPST switch.

Squarebot – General
The basic robot supplied as a starting design for the Vex Starter Kit, named for the square shape of its structural frame. It can be built by following the building directions in each subsystem chapter. New Vex Inventors are encouraged to start by building and experimenting with the Squarebot, then modifying it for their own purposes. Experienced Vex inventors can use the Squarebot design for reference purposes.

Stability - Structure Subsystem
The ability of a robot to remain upright and steady while moving over terrain and traversing obstacles.

Stall (Motor) – Motion Subsystem
A condition where a motor encounters so much resistance that it cannot turn. It is damaging for the motor to be in this condition. This condition can be avoided through the use of a clutch, which will disengage the motor when too much resistance is encountered.

Stick Mode - Control Subsystem
An advanced feature of the Transmitter that allows control channels 2 and 3 to trade places on the joysticks (2 becomes the right stick's vertical axis and 3 becomes the left stick's vertical axis). The default mode is 2, and should not be changed under most circumstances.

glossary

Stress (Structural) – Structure Subsystem
Physical forces acting on an object constitute mechanical stress. Too much stress concentrated on a small area can cause parts to break.

Structure Subsystem
The subsystem responsible for holding the rest of the subsystems together and in place, and for protecting them from physical harm, as much as possible.

Subsystem – General
A subdivision of a system that helps to organize the system into convenient compartmentalized functions. The lines between subsystems are not always perfectly clear (for example, a wheel's axle is both a motion-transferring device and a physical support), but they work to give a general idea of purpose for the components in a system.

Support – Structure Subsystem
The degree of physical stability a piece has, owing to the strength of the foundation provided by the other pieces which are holding it in place. A piece which provides a physical brace or foundation for another piece is also called a support.

Support Polygon – Structure Subsystem
The imaginary polygon formed by connecting all the points at which the robot touches the ground. In cases where the arrangement of ground contact points is complex, the support polygon is the largest convex polygon that can be formed by those points. If the center of mass of the robot is not directly over the support polygon (i.e. projecting a line straight down from the center of gravity would not intersect the support polygon) at all times, the robot will fall over.

t

Tank-style Controls – Control Subsystem
A Transmitter driving mode in which the robot is controlled with only the vertical axes of the joysticks. Each joystick controls the motion of one side of the robot, like an old tank. Also called 23 mode because axes 2 and 3 are being used to drive the robot.

Tether – Control Subsystem
A cable used to connect the Transmitter directly to the Micro Controller. Using a tether allows you to control the robot by sending signals through the cable rather than through the air, eliminating the possibility of radio interference. A tether cable is not included with the Starter Kit. You can use any telephone handset cable (the one that goes from the base to the handset of a corded phone) as a tether.

Threaded – Structure Subsystem
A threaded piece has threading on or in it, which allows a screw to be fastened into it. Threading is the tiny spiraling texture on the outside of a screw or the inside of a nut (for example) that allows a screw to be locked into place.

Torque – Motion Subsystem
Angular ("spinning") force. Torque can be converted into linear ("pushing") force where a wheel comes in contact with the ground.

Traction - Motion Subsystem
An overall measure of how well a tire is able to grip the ground. Many factors (texture, size, material, etc.) must be taken into account when evaluating a tire's traction on different surfaces.

Transmitter – Control Subsystem
The primary user interface device for the human operator of the robot. The Transmitter gathers input from its two joysticks and four buttons, and transmits them via FM radio wave to the RF Receiver mounted on the robot.

Transmitter Battery Holder – Power Subsystem
The battery container for the Transmitter. The battery holder contains the 8 NiCd AA batteries in place required to operate the Transmitter. If you wish to use the 9.6V battery pack (part of the Vex Power Pack accessory kit), the Battery Box can be easily removed to make room for the 9.6V pack.

glossary

Transmitter Frequency Module – Control Subsystem
The swappable module in back of the Transmitter that designates the radio frequency that the Transmitter will use to communicate with the RF Receiver Module. The frequency of the Transmitter Frequency Module must match the frequency of the crystal installed in the RF Receiver Module on the robot in order for them to communicate. All Vex Starter Kits come with the same Transmitter Frequency Module. Additional modules on different frequencies are available for purchase separately.

Trickle Charge – Power Subsystem
A very low-power charge that is applied to full batteries in order to keep them full. A trickle charge counteracts a battery's natural loss of charge over time, so that the battery can be left on the charger, and still always maintain a full charge.

Trim - Control Subsystem
The calibration setting for the joysticks on the Transmitter. Also, the name of the menu on the Transmitter that allows for fine tuning of these settings.

V

Vex Power Pack - Power Subsystem
A Vex Robotics Design System accessory kit with high-capacity rechargeable NiCd battery packs for the robot and Transmitter, and a charger.

Voltage (Battery) - Power Subsystem
The electrical voltage difference between the + and – terminals on a battery. Different batteries and battery packs have different starting voltages. Voltage falls (though not all the way to 0) as the battery's power is used up, and can be used as a rough indicator of the amount of capacity remaining on a battery.

Voltage (Electrical) - Power Subsystem
The difference in electrical potential between two points in space. An electron or other charged particle has more energy at one of the two points, and will tend to move toward the other point.

Voltage Drop - Power Subsystem
A phenomenon exhibited by rechargeable batteries where a battery that is frequently "shallow discharged" (discharged only a little between recharges) will begin to experience reduced performance. This can be reversed by discharging the batteries to a nearly-empty safe level (when the robot automatically turns off, for example–NOT by shorting them or draining them to 0V by external means!) and then recharging them to full capacity. Repeating the drain-charge cycle a few times should restore the batteries to full performance.

W

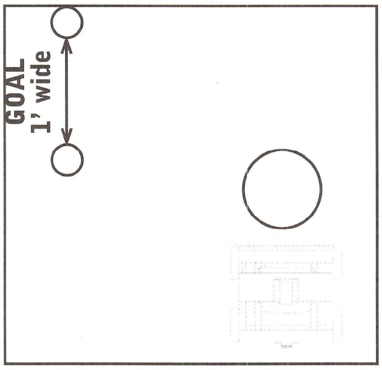
Washer - Structure Subsystem
A round metal or plastic disc placed between a screw head and the surface to which it is mounted. The washer gives the screw a secure surface to brace against, and prevents the screw head from bending the metal surrounding the hole and popping all the way through. Steel washers should be used with screws that are not meant to move at all. Delrin (white plastic) washers should be used when the entire screw-nut assembly is meant to turn together (e.g. the screw at the pivot of a movable arm attachment).

single-player challenges

These starter challenges will give you some fun, yet demanding goals to work toward as you build your first robots. Pick either a single- or multi-player challenge and get ready to build!

For additional (and more advanced) challenges, visit the official Vex Robotics Design System website at http://www.vexrobotics.com!

Challenge 1
Name: Solo Soccer
Difficulty: Novice to Intermediate

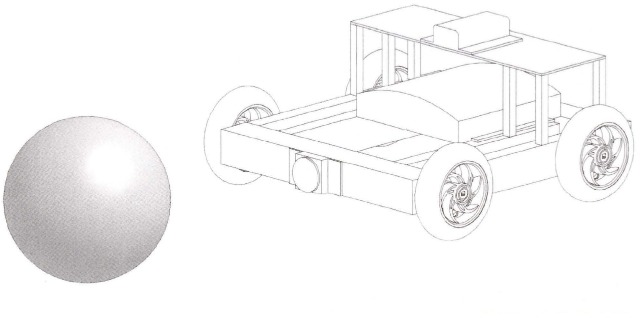


Course: Flat carpeted (easy) or smooth (harder) surface, two static objects as goal markers, a baseball/tennis ball or similar-sized round object placed in the middle of the field.

Engineering Objective: Verify robot functionality and familiarize the robot operator with controls.

Instructions: Maneuver your robot to push the ball into the "goal" (i.e. between the two markers). More advanced teams should attempt to engineer a better solution to ball handling than just pushing the ball around with the front chassis bumper. Hint: Make sure the ball does not hit the bumper sensor on the front of the Squarebot, or the operator will temporarily lose control!

Other Rules: Your robot must include the bumper sensor (plugged into ports 9 and 10) on both the front and the back in the same approximate location as the Squarebot.



single-player challenges

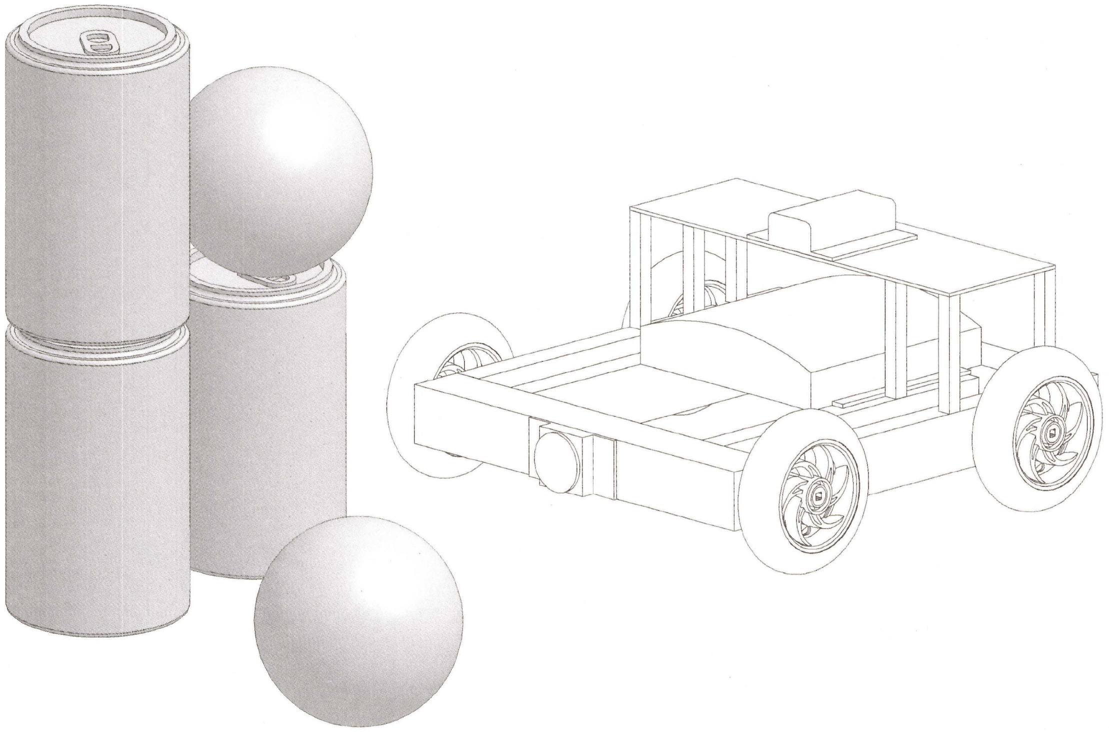
Challenge 2
Name: Orchard
Difficulty: Intermediate

Course: Flat surface, two "stacks" of different heights, two baseballs or tennis balls (one on each stack)

Engineering Objective: Design a robust mechanical solution to a physical-space problem

Instructions: The robot must knock the balls off each of the two stacks without knocking over the cans.

Hint: A static structure may not be the best solution, a servomotor-guided solution would work better.



For more solo challenges, check out the Vex website at http://www.vexrobotics.com!

multi-player challenges

Challenge 3
Name: Team Soccer
Difficulty: Novice to Intermediate

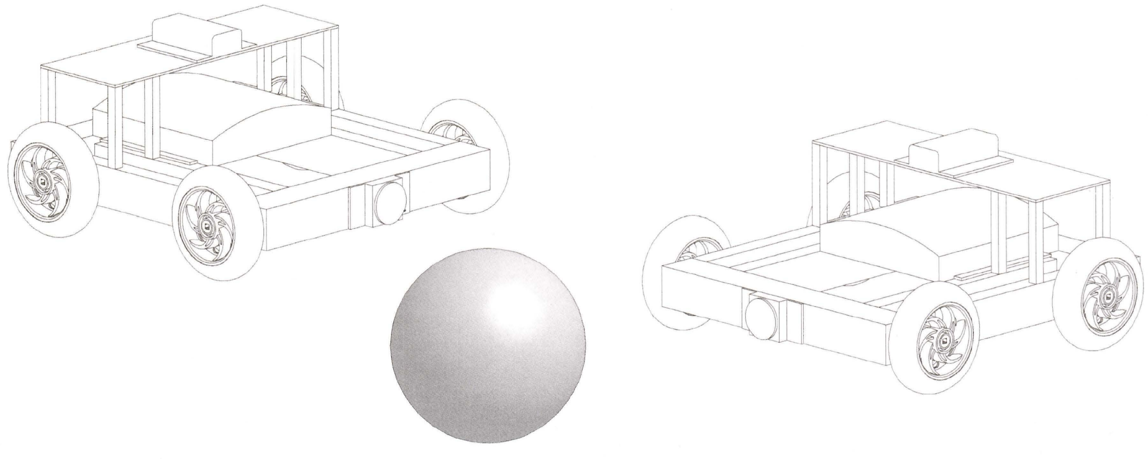
Course: Flat carpeted (easy) or smooth (harder) surface, 2x (two static objects) as goal markers, a baseball/tennis ball or similar-sized round object placed in the middle of the field

Engineering Objective: Verify robot functionality and familiarize the robot operator with controls. Build inter-team cooperation skills when there are enough robots to put more than one on a team.

Instructions: Maneuver your robot to push the baseball into your opponent's "goal" (i.e. between the two markers). Defend your own goal! Robots are not allowed to sit in their goal areas in order to defend, they must stay at least 1' away from their goals at all times.

More advanced teams should attempt to engineer a better solution to ball handling than just pushing the ball around with the front chassis bumper. You may not remove or cover the robot's bumper sensors, in an attempt to make it harder for other teams to hit them.

Hint: Make sure the ball does not hit the bumper sensor on the front of the Squarebot, or the operator will temporarily lose control! Try to hit your opponent's sensors to disable them!



multi-player challenges

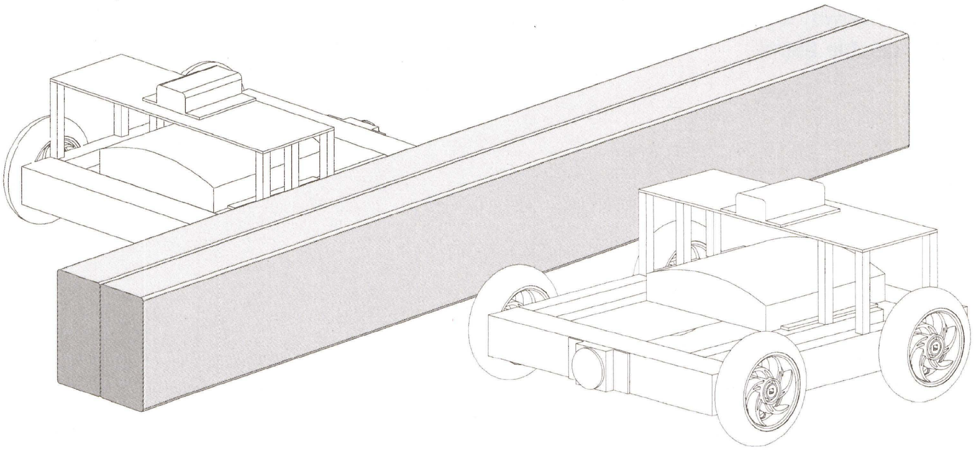
Challenge 4:
Name: Demolition Derby
Difficulty: Intermediate

Course: Two pieces of 2x4 lumber marking the center "island" of an oval race track.

Engineering Objective: Engineer a robust robot design for good performance characteristics

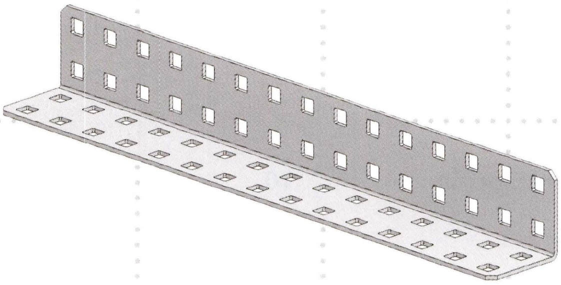
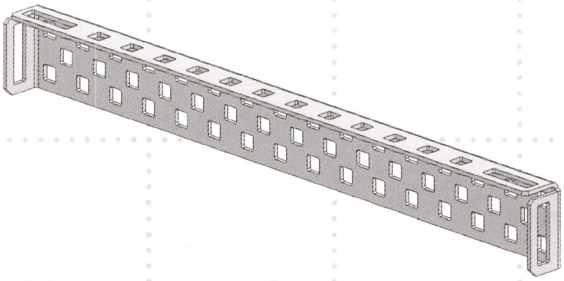
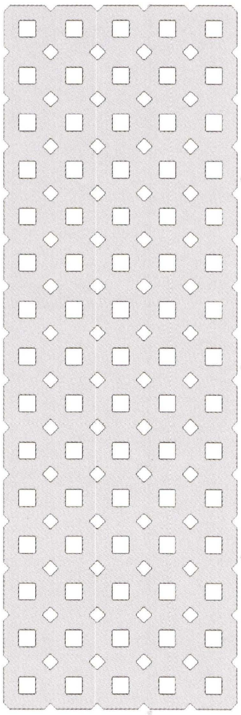
Instructions: Be the first to complete ten laps around the center island. Bumper sensors must be mounted in the "Squarebot" positions and accessible. Collisions are frequent in this event, so be SURE your robot is built to withstand impact from all angles!

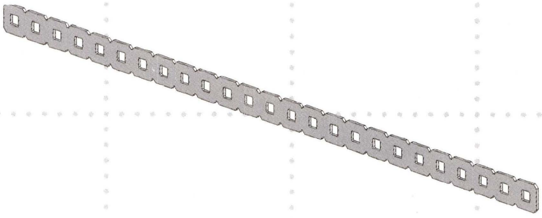
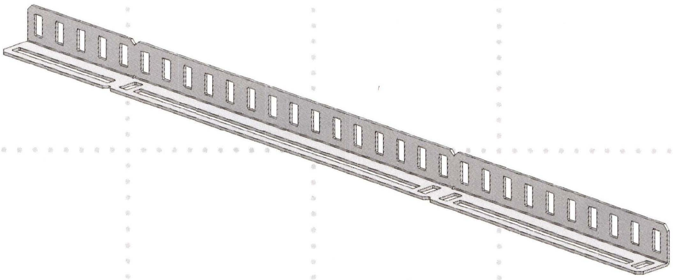
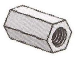
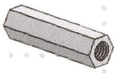
Note: Robots built with protrusions or other elements which could be considered dangerous to people or intended to damage other robots are automatically disqualified. Safety first!



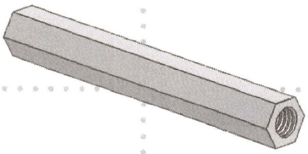
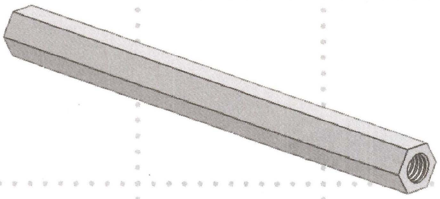
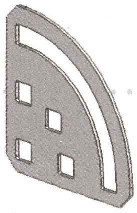
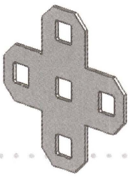
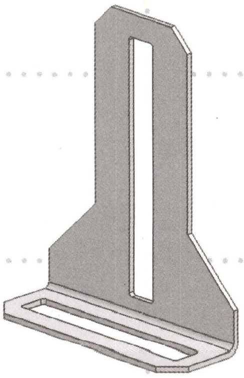
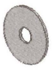
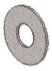
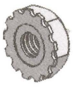
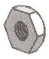
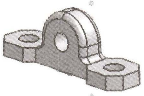
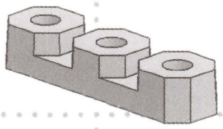
For more multi-robot challenges and information on competitions or leagues in your area, check out the Vex website at http://www.vexrobotics.com!

complete inventory

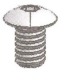
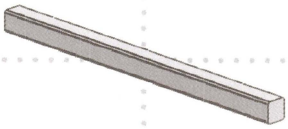
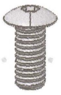
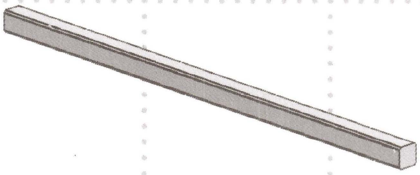
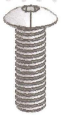
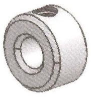
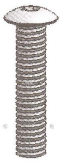
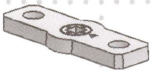
component	qty
chassis bumper 	**2**
chassis rail 	**4**
plate 	**2**

component	qty
long bar 	**4**
long angle bar 	**4**
fully threaded beams (½") 	**10**
fully threaded beams (1") 	**8**

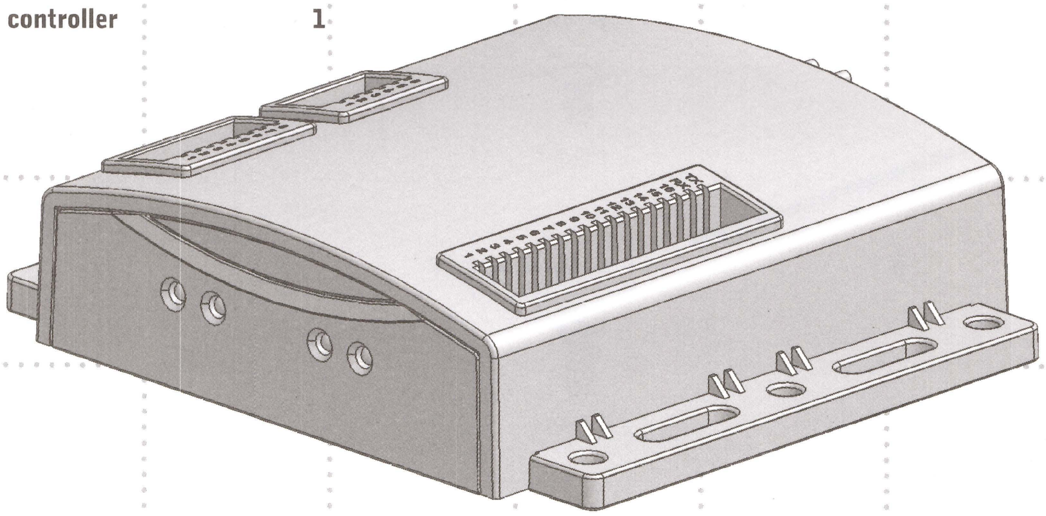
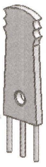
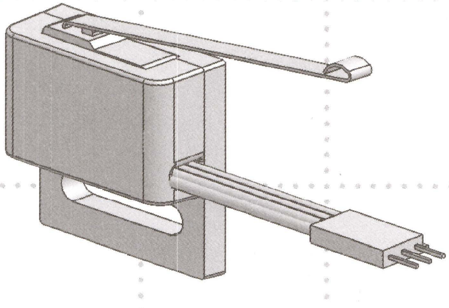
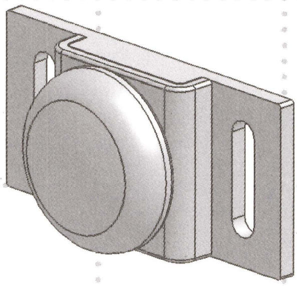
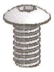
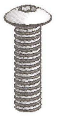
complete inventory, continued

component	qty
partially threaded beams (2") 	4
partially threaded beams (3") 	4
pivot 	2
plus gusset 	2
gusset 	2
washer, steel  Full size	30
washer, delrin  Full size	10
keps nut (¼")  Full size	65
lock nut (¼")  Full size	14
bearing block 	6
bearing flat 	16

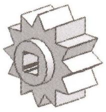
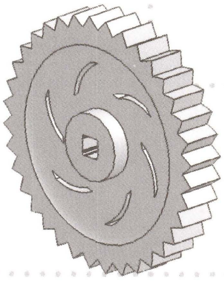
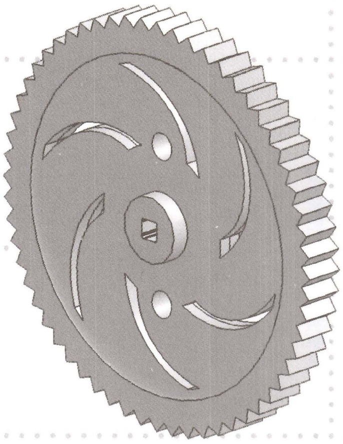
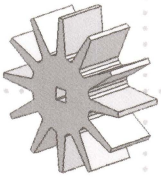
complete inventory, continued

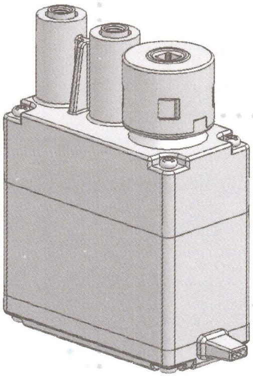
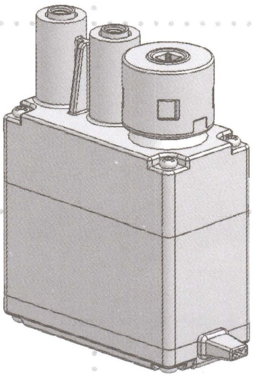
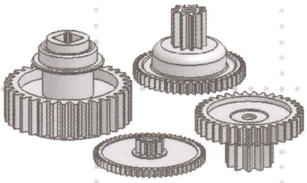
component	qty	component	qty
square bar (12") 	2	**screw 8-32 x ¼"**  Full size	70
square bar (2") 	4	**screw 8-32 x ⅜"**  Full size	28
square bar (3") 	4	**screw 8-32 x ½"**  Full size	28
collar 	16	**screw 8-32 x ¾"**  Full size	14
threaded screw for collar Full size	16	**lock plate** 	4
plastic spacer .318" 	20	**plastic spacer .182"** 	20

complete inventory, continued

component	qty	component	qty
controller	1		
			
jumper clip	5		
			
limit switch	2	**bumper switch**	2
			
motor screw 6-32 x ¼"	10	**motor screw 6-32 x ½"**	10
 Full size		 Full size	

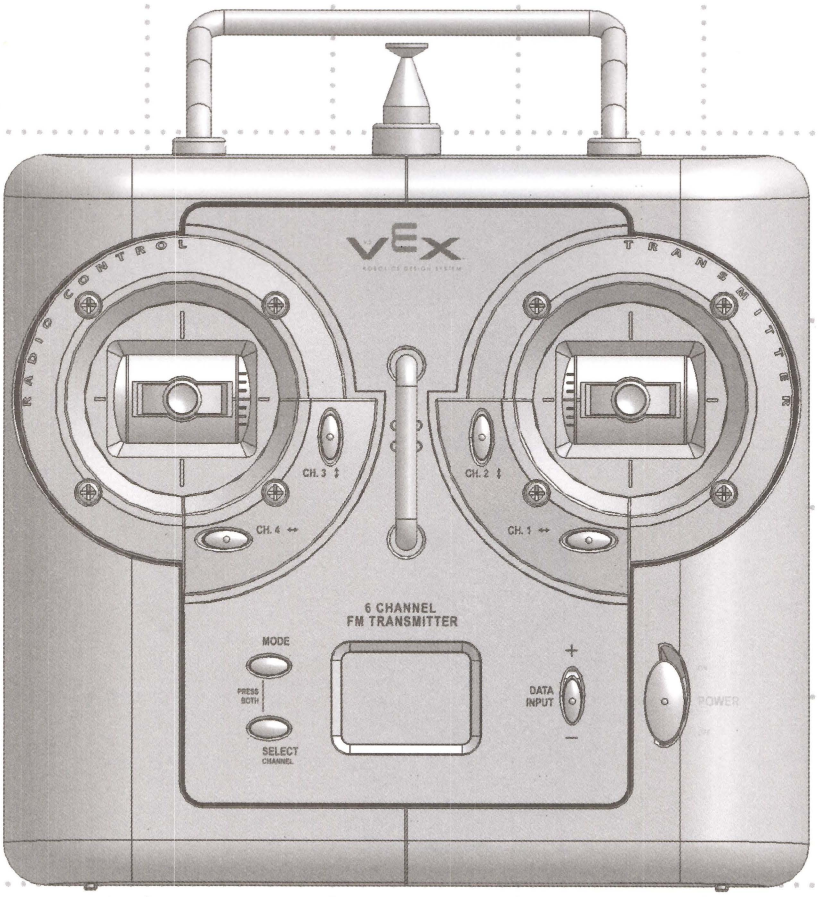
complete inventory, continued

component	qty
12-tooth gear 	4
36-tooth gear 	4
60-tooth gear 	4
intake roller 	2

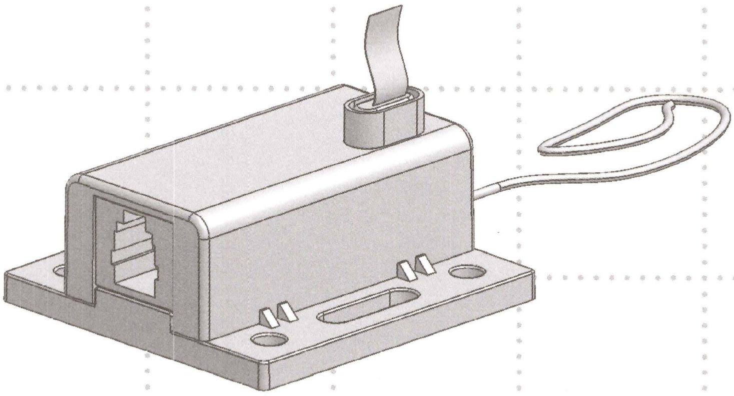
component	qty
servo motor 	1
motor assembly 	3
replacement gears (4 per set) 	2
clutch post 	4

complete inventory, continued

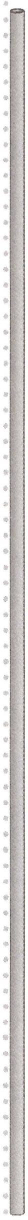
component	qty
transmitter	1


RADIO CONTROL TRANSMITTER
VEX
ROBOTICS DESIGN SYSTEM
CH. 3
CH. 2
CH. 4
CH. 1
6 CHANNEL FM TRANSMITTER
MODE
PRESS BOTH
SELECT CHANNEL
+
DATA INPUT
−
POWER

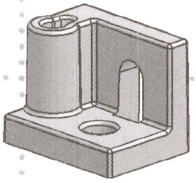
RF receiver module	1



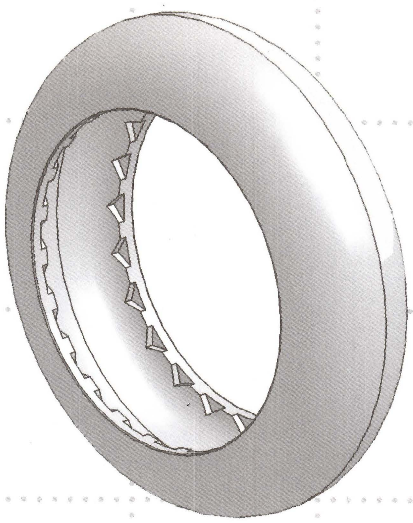
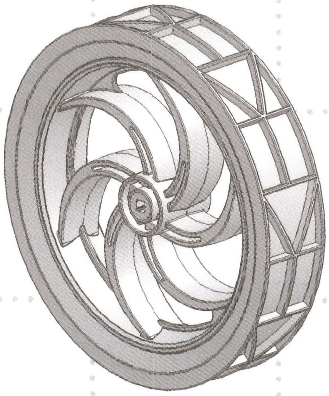
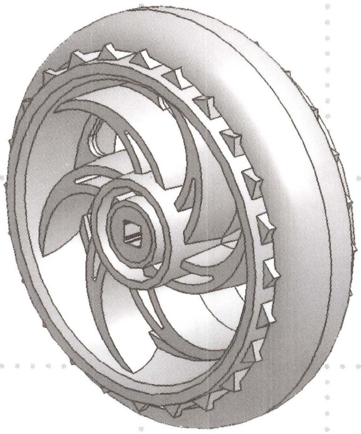
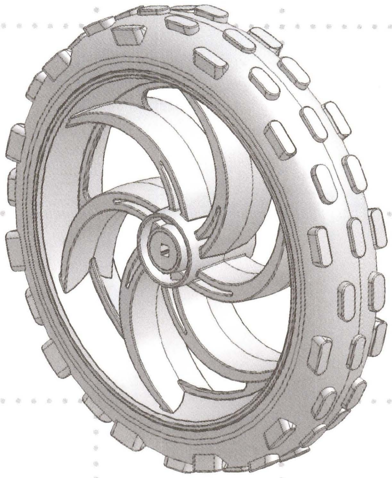
component	qty
receiver antenna sleeve	1



receiver antenna sleeve holder	1

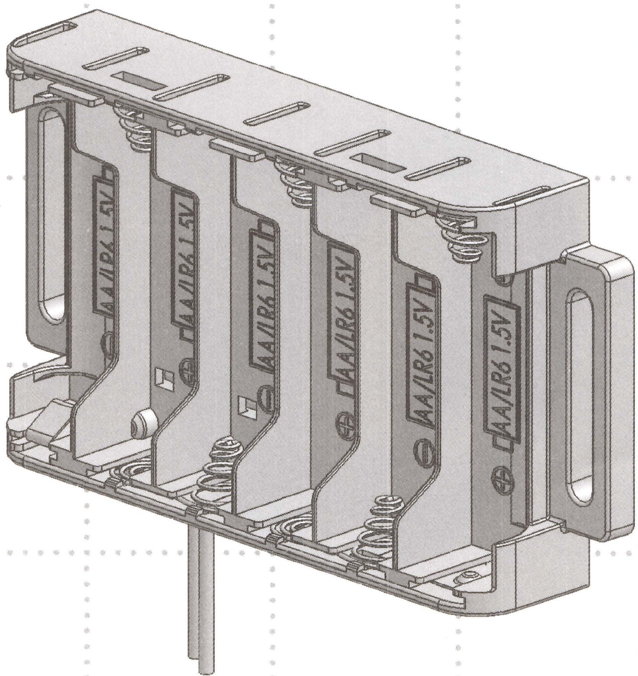


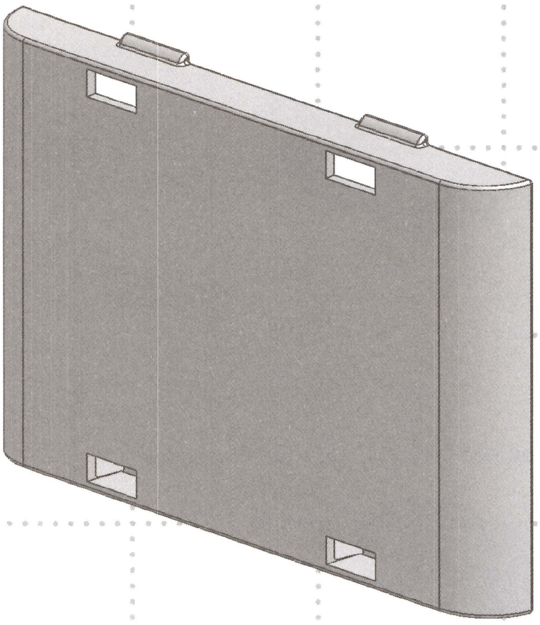
complete inventory, continued

component	qty	component	qty
removable tire	4	all-purpose tire	2
			
1.895" hub for removable tire	4	knobby tire	2
			

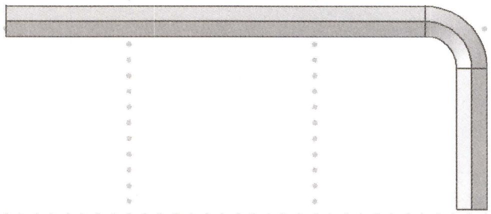
complete inventory, continued

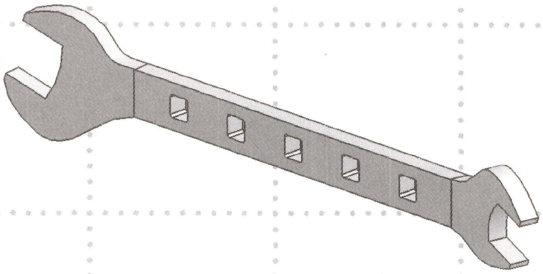
component	qty	component	qty
battery holder with lid	1		



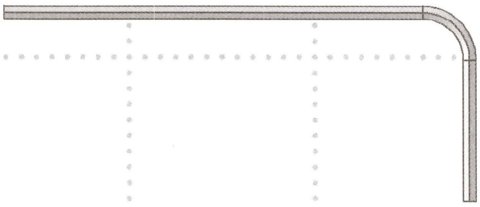


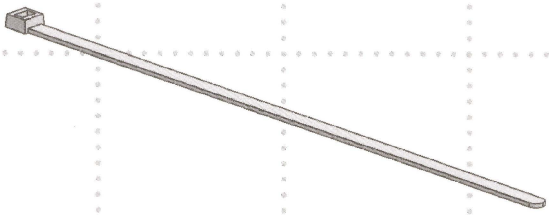
component	qty	component	qty
3/32" hex L driver	1	**wrench**	1





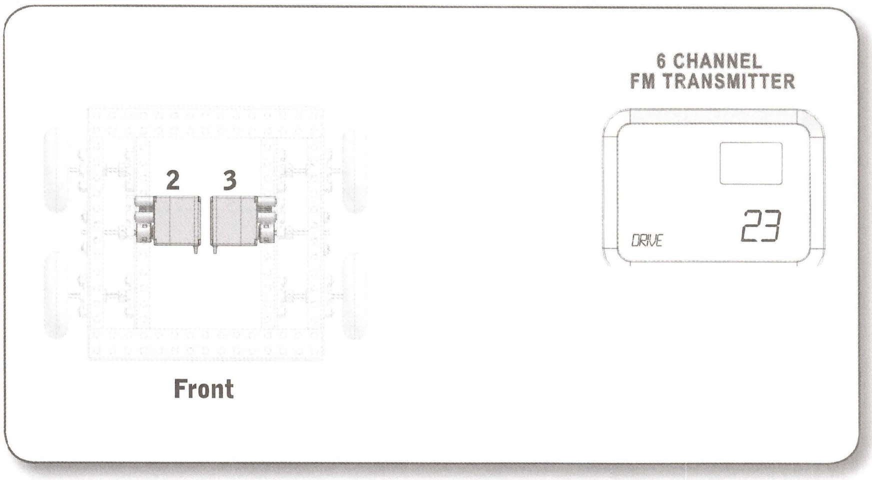
component	qty	component	qty
5/64" hex L driver	1	**wire tie (4")**	100



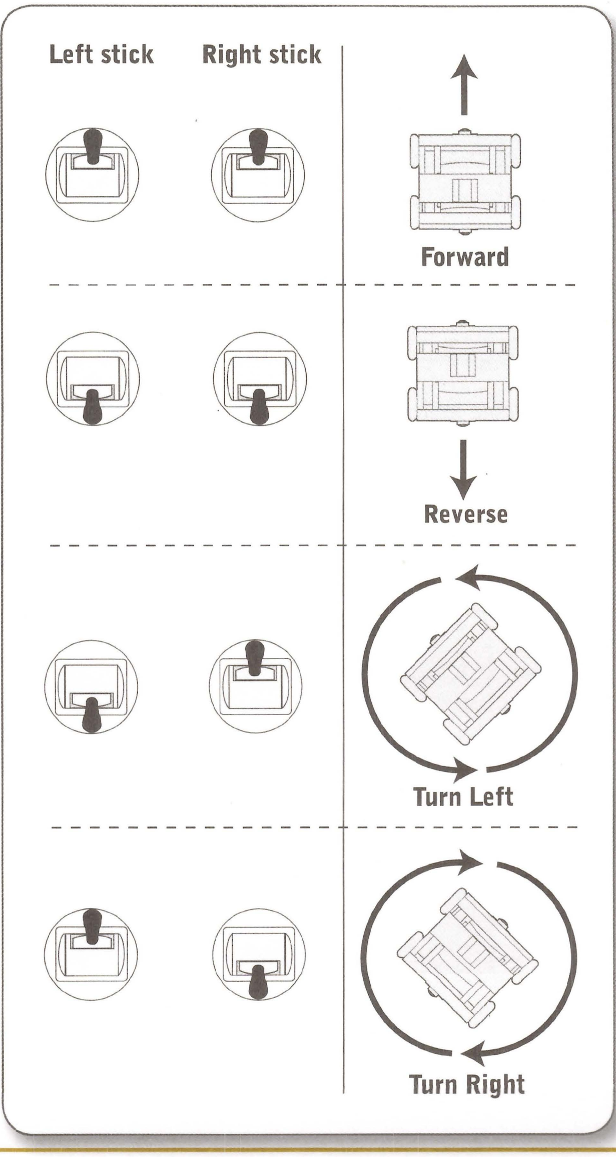


tank-style controls

For a 2-motor configuration, the left motor should plug into Motor Port 3, and the right motor should plug into Motor Port 2. The following controls will then apply.


2
3
Front
6 CHANNEL
FM TRANSMITTER
DRIVE
23

In this configuration, every joystick "control channel" controls its same-numbered motor port.


Left stick
Right stick
Forward
Reverse
Turn Left
Turn Right

tank-style controls, continued

Transmitter in "23 mode", no jumpers set on Micro Controller

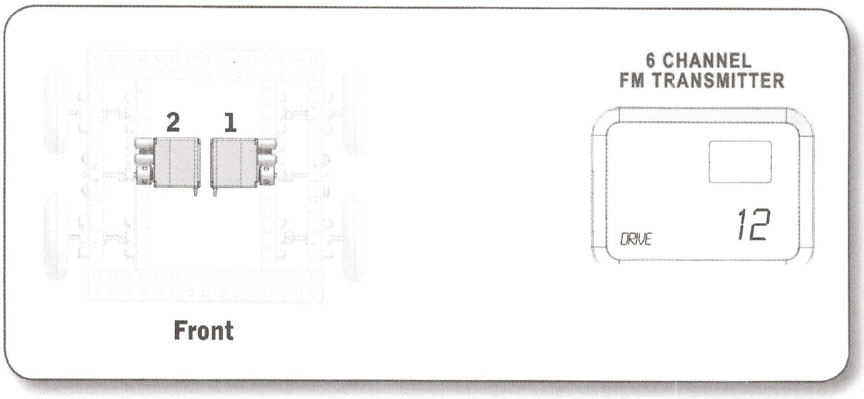
CW= clockwise
CCW = counter-clockwise

	Motor 1	Motor 2	Motor 3	Motor 4	Motor 5	Motor 6	Motor 7	Motor 8
Channel 1								
Stick Left	CW							
Stick Right	CCW							
Channel 2								
Stick Up		CW						
Stick Down		CCW						
Channel 3								
Stick Up			CCW					
Stick Down			CW					
Channel 4								
Stick Left				CW				
Stick Right				CCW				
Channel 5								
Top Button					CCW		CW	
Bottom Button					CW		CCW	
Channel 6								
Top Button						CCW		CW
Bottom Button						CW		CCW

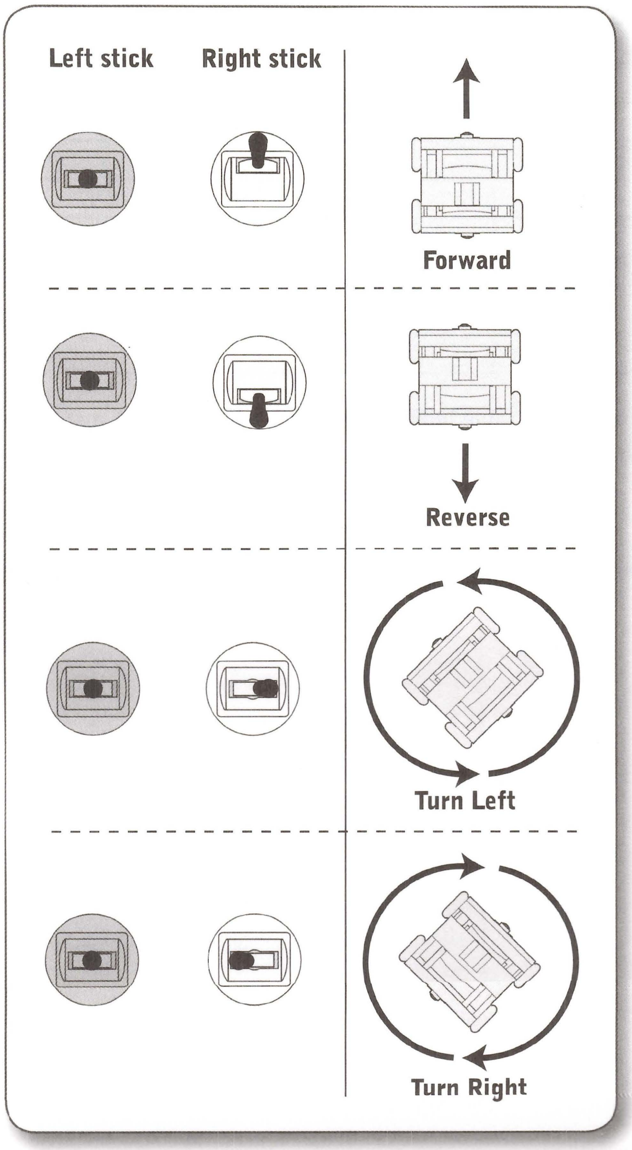
The directions listed in this table indicate the direction of spin for a standard Vex Motor Module. Vex Servo Modules will turn in the opposite direction.

arcade-style controls

For a 2-motor configuration, the left motor should plug into Motor Port 1, and the right motor should plug into Motor Port 2. The following controls will then apply.


2
1
Front
6 CHANNEL FM TRANSMITTER
DRIVE
12

In this configuration, the first two control channels are mixed controls that affect both Motor Ports 1 and 2. The remaining joystick "control channels" controls their same-numbered motor ports directly.


Left stick
Right stick
Forward
Reverse
Turn Left
Turn Right

arcade-style controls, continued

Transmitter in "12 mode", no jumpers set on Micro Controller

CW= clockwise
CCW = counter-clockwise

	Motor 1	Motor 2	Motor 3	Motor 4	Motor 5	Motor 6	Motor 7	Motor 8
Channel 1								
Stick Left	CW	CW						
Stick Right	CCW	CCW						
Channel 2								
Stick Up	CCW	CW						
Stick Down	CW	CCW						
Channel 3								
Stick Up			CCW					
Stick Down			CW					
Channel 4								
Stick Left				CW				
Stick Right				CCW				
Channel 5								
Top Button					CCW		CW	
Bottom Button					CW		CCW	
Channel 6								
Top Button						CCW		CW
Bottom Button						CW		CCW

The directions listed in this table indicate the direction of spin for a standard Vex Motor Module. Vex Servo Modules will turn in the opposite direction.

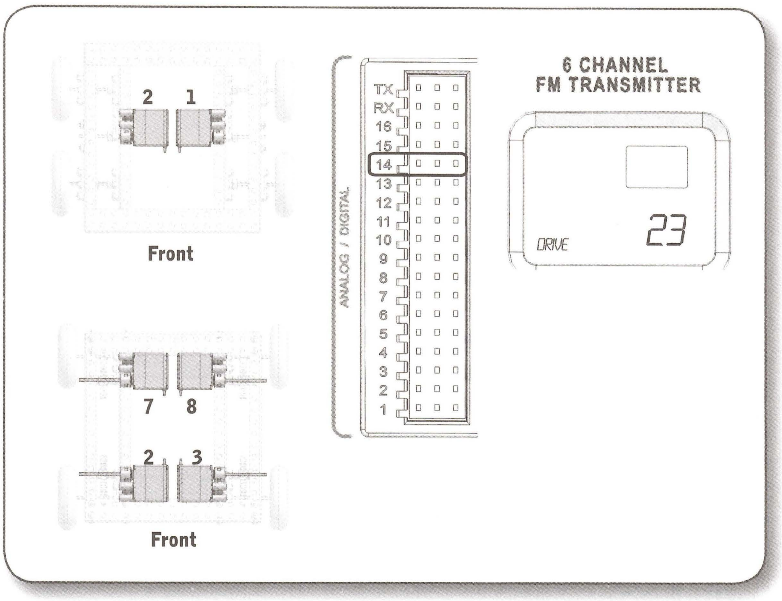
alternate arcade-style controls

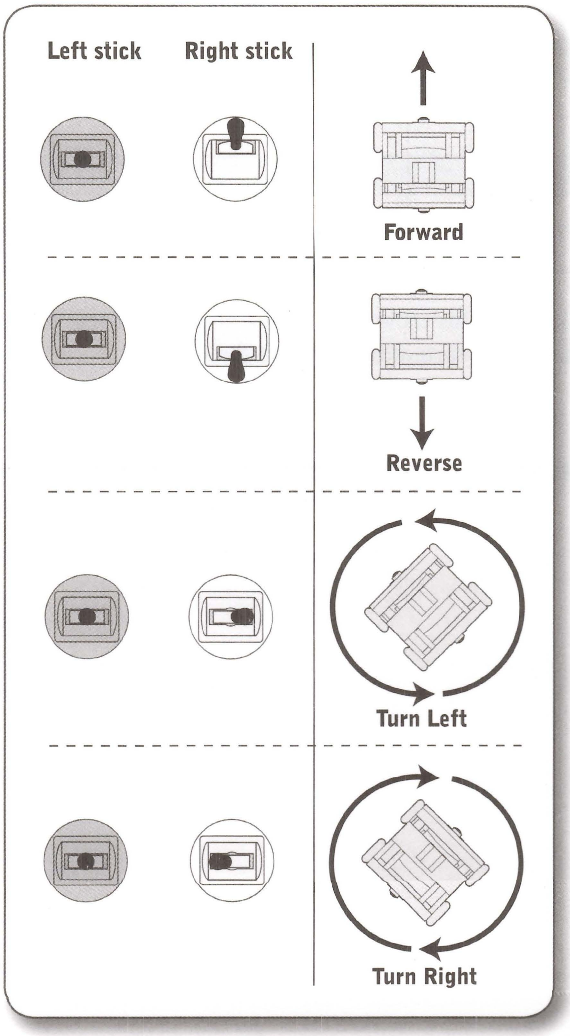
For a 2-motor configuration, the left motor should plug into Motor Port 1, and the right motor should plug into Motor Port 2.

For a 4-motor configuration, the front left motor should plug into Motor Port 3, and the front right motor should plug into Motor Port 2. The rear left motor should go into Motor Port 8, and the rear right motor should go into Motor Port 7. The following controls will then apply.

In this configuration, the first two control channels are mixed controls that affect both Motor Ports 1 and 2. This mode is set to also allow the use of a four-motor design (requires an additional motor, sold separately), so Motor Ports 7 and 8 are also tied into the sticks so that both of the left side motors move together, and both of the right side motors move together. The remaining joystick "control channels" controls their same-numbered motor ports directly.

The difference between the Transmitter "12" and using Jumper 14 is that the Transmitter "12" will perform the mixing functions before the signal is sent out from the Transmitter, while the Jumper 14 version will perform those calculations on the Micro Controller. They perform the calculations in slightly different ways. The Transmitter version will only allow you to move 60% of full power straight forward or backward, but will speed up going into turns. The Jumper version will allow you to go full speed forward or backward, but will slow down going into turns.





alternate arcade-style controls, continued

Transmitter in "23 mode", Jumper 14 set on Micro Controller

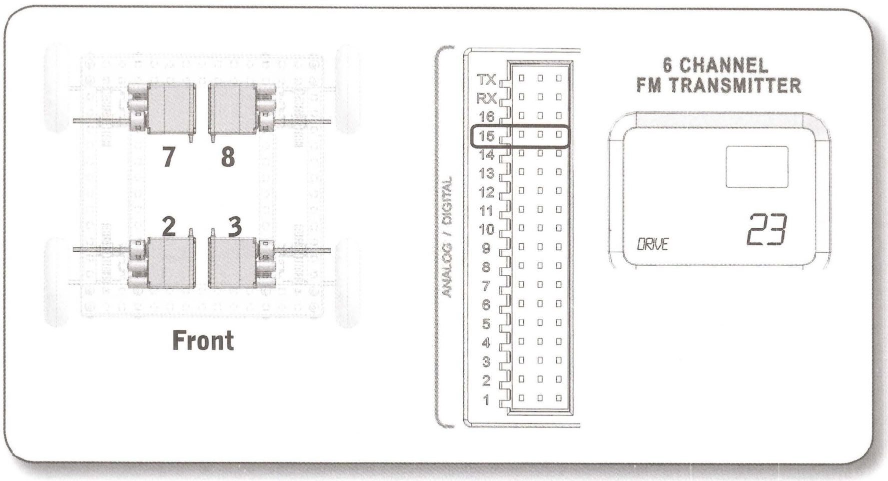
CW= clockwise
CCW = counter-clockwise

	Motor 1	Motor 2	Motor 3	Motor 4	Motor 5	Motor 6	Motor 7	Motor 8
Channel 1								
Stick Left	CW							
Stick Right	CCW							
Channel 2								
Stick Up		CW					CW	
Stick Down		CCW					CCW	
Channel 3								
Stick Up			CCW					CCW
Stick Down			CW					CW
Channel 4								
Stick Left				CW				
Stick Right				CCW				
Channel 5								
Top Button					CCW			
Bottom Button					CW			
Channel 6								
Top Button						CCW		
Bottom Button						CW		

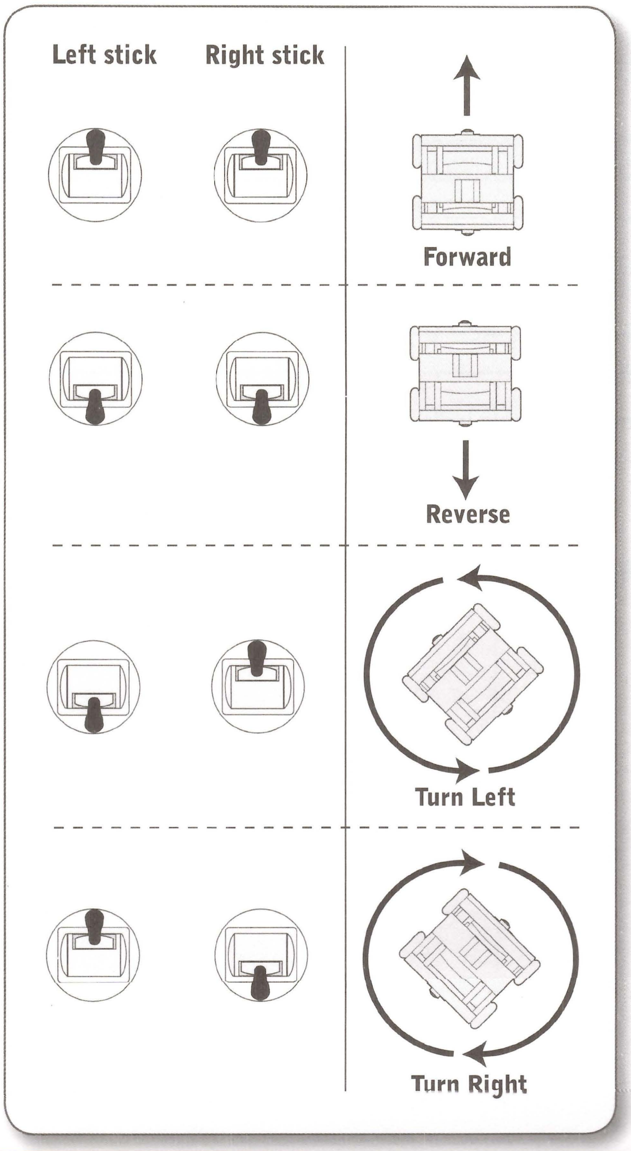
The directions listed in this table indicate the direction of spin for a standard Vex Motor Module. Vex Servo Modules will turn in the opposite direction.

tank-style controls (4WD)

For a 4-motor configuration, the front left motor should plug into Motor Port 3, and the front right motor should plug into Motor Port 2. The rear left motor should go into Motor Port 8, and the rear right motor should go into Motor Port 7. The following controls will then apply.


7
8
2
3
Front
TX
RX
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
ANALOG / DIGITAL
6 CHANNEL FM TRANSMITTER
DRIVE
23

This configuration is the same as the basic "23 mode" as far as driving goes, except that pushing the stick causes both motors on the same side to be powered at once rather than just one.


Left stick
Right stick
Forward
Reverse
Turn Left
Turn Right

tank-style controls (4WD), continued

Transmitter in "23 mode", Jumper 15 set on Micro Controller

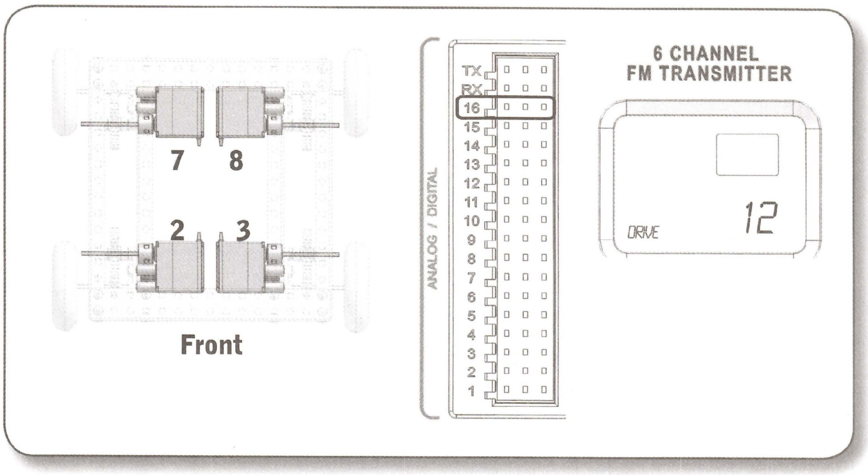
CW= clockwise
CCW = counter-clockwise

	Motor 1	Motor 2	Motor 3	Motor 4	Motor 5	Motor 6	Motor 7	Motor 8
Channel 1								
Stick Left	CW							
Stick Right	CCW							
Channel 2								
Stick Up		CW					CW	
Stick Down		CCW					CCW	
Channel 3								
Stick Up			CCW					CCW
Stick Down			CW					CW
Channel 4								
Stick Left				CW				
Stick Right				CCW				
Channel 5								
Top Button					CCW			
Bottom Button					CW			
Channel 6								
Top Button						CCW		
Bottom Button						CW		

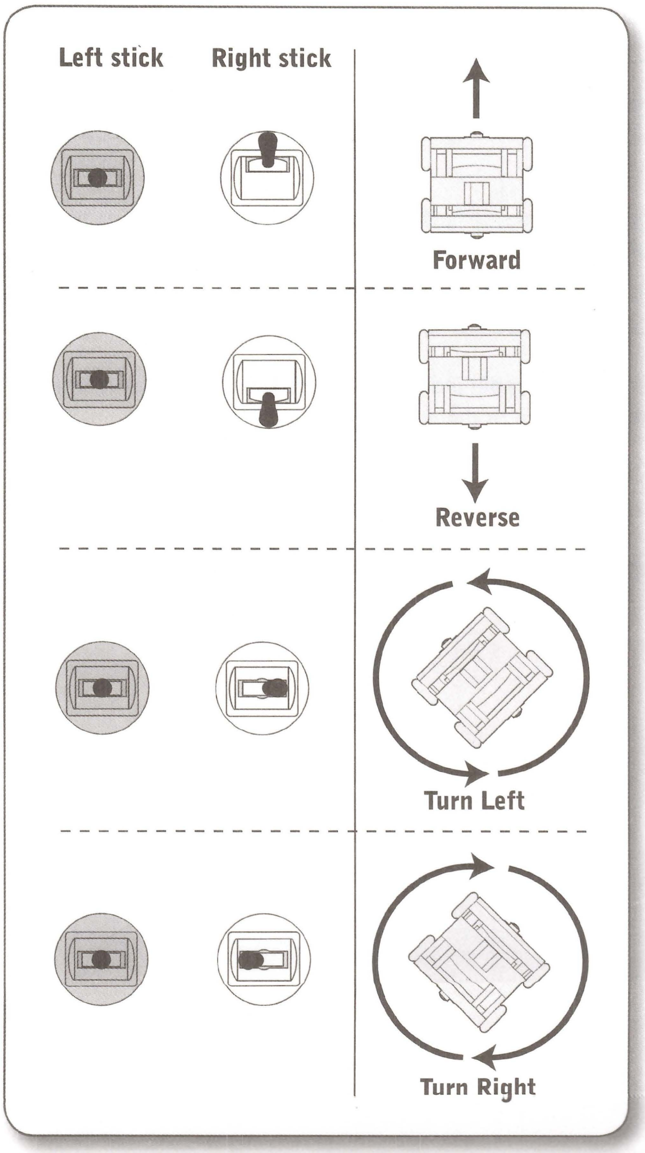
The directions listed in this table indicate the direction of spin for a standard Vex Motor Module. Vex Servo Modules will turn in the opposite direction.

arcade-style controls (4WD)

For a 4-motor configuration, the front left motor should plug into Motor Port 3, and the front right motor should plug into Motor Port 2. The rear left motor should go into Motor Port 8, and the rear right motor should go into Motor Port 7. The following controls will then apply.


7
8
2
3
Front
TX
RX
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
ANALOG / DIGITAL
6 CHANNEL
FM TRANSMITTER
DRIVE
12

This configuration is the same as the basic "12 mode" as far as driving goes, except that the command mixes will drive both motors on the same side at once. Remember that the "Jumper 14" / "software 12 mix" mode will also allow the use of 4WD in an arcade-style control, but with slightly different control characteristics (see original User Guide pages on control layout).


Left stick
Right stick
Forward
Reverse
Turn Left
Turn Right

arcade-style controls (4WD), continued

Transmitter in "12 mode", Jumper 16 set on Micro Controller

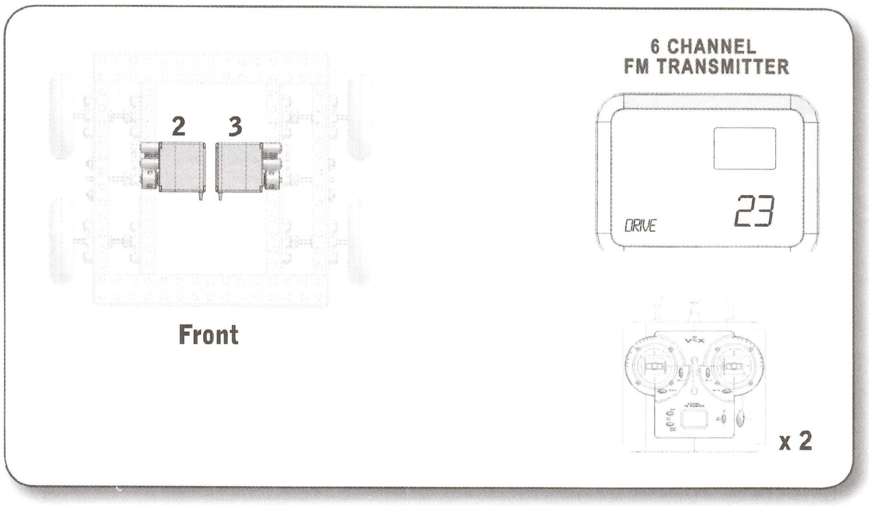
CW= clockwise
CCW = counter-clockwise

	Motor 1	Motor 2	Motor 3	Motor 4	Motor 5	Motor 6	Motor 7	Motor 8
Channel 1								
Stick Left	CW	CW					CW	CW
Stick Right	CCW	CCW					CCW	CCW
Channel 2								
Stick Up	CCW	CW					CW	CCW
Stick Down	CW	CCW					CCW	CW
Channel 3								
Stick Up			CCW					
Stick Down			CW					
Channel 4								
Stick Left				CW				
Stick Right				CCW				
Channel 5								
Top Button					CCW			
Bottom Button					CW			
Channel 6								
Top Button						CCW		
Bottom Button						CW		

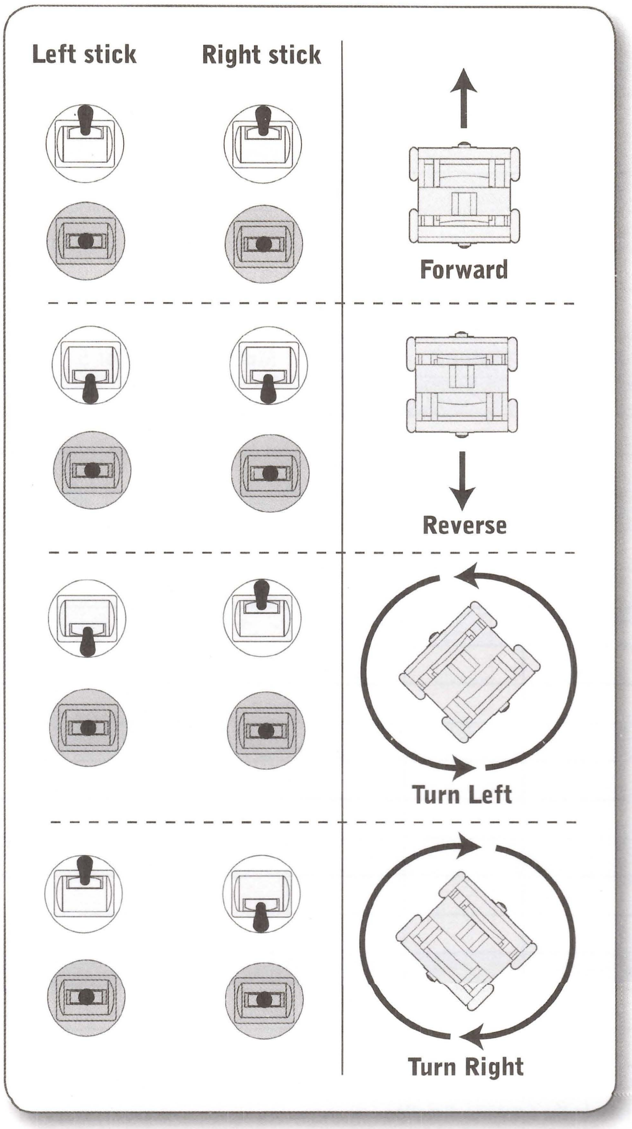
The directions listed in this table indicate the direction of spin for a standard Vex Motor Module. Vex Servo Modules will turn in the opposite direction.

tank-style controls (two transmitters)

For a 2-motor configuration, the left motor should plug into Motor Port 3, and the right motor should plug into Motor Port 2. The following controls will then apply for the driver (operator on the first transmitter).


2
3
Front
6 CHANNEL
FM TRANSMITTER
DRIVE
23
x 2

In this configuration, the first two control channels on the first transmitter are mixed controls that affect both Motor Ports 1 and 2. The second transmitter is used to control some sort of attachment, based on the challenge being attempted. The second transmitter is not placed into "12 mode," as it is designed to work precisely with challenge-based robot attachments by using different sticks (so you can't accidentally affect robot operation by moving the stick on an axis you didn't want—the horizontal axes don't do anything).


Left stick
Right stick
Forward
Reverse
Turn Left
Turn Right

tank-style controls (two transmitters), continued

Both transmitters in "23 mode", no jumpers set on Micro Controller

CW= clockwise
CCW = counter-clockwise

TRANSMITTER 1

	Motor 1	Motor 2	Motor 3	Motor 4	Motor 5	Motor 6	Motor 7	Motor 8
Channel 1								
Stick Left	CW							
Stick Right	CCW							
Channel 2								
Stick Up		CW						
Stick Down		CCW						
Channel 3								
Stick Up			CCW					
Stick Down			CW					
Channel 4								
Stick Left								
Stick Right								
Channel 5								
Top Button				CCW				
Bottom Button				CW				
Channel 6								
Top Button								
Bottom Button								

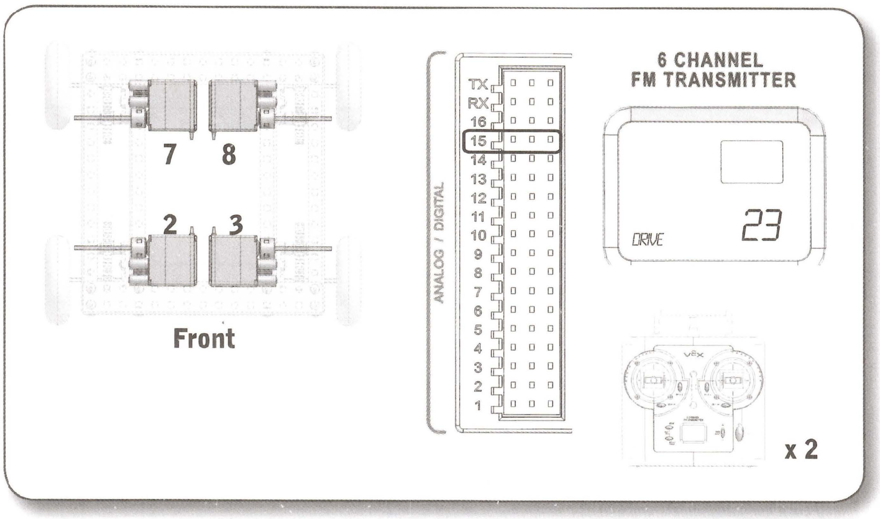
TRANSMITTER 2

	Motor 1	Motor 2	Motor 3	Motor 4	Motor 5	Motor 6	Motor 7	Motor 8
Channel 1								
Stick Left								
Stick Right								
Channel 2								
Stick Up					CW			
Stick Down					CCW			
Channel 3								
Stick Up						CCW		
Stick Down						CW		
Channel 4								
Stick Left								
Stick Right								
Channel 5								
Top Button							CCW	
Bottom Button							CW	
Channel 6								
Top Button								CCW
Bottom Button								CW

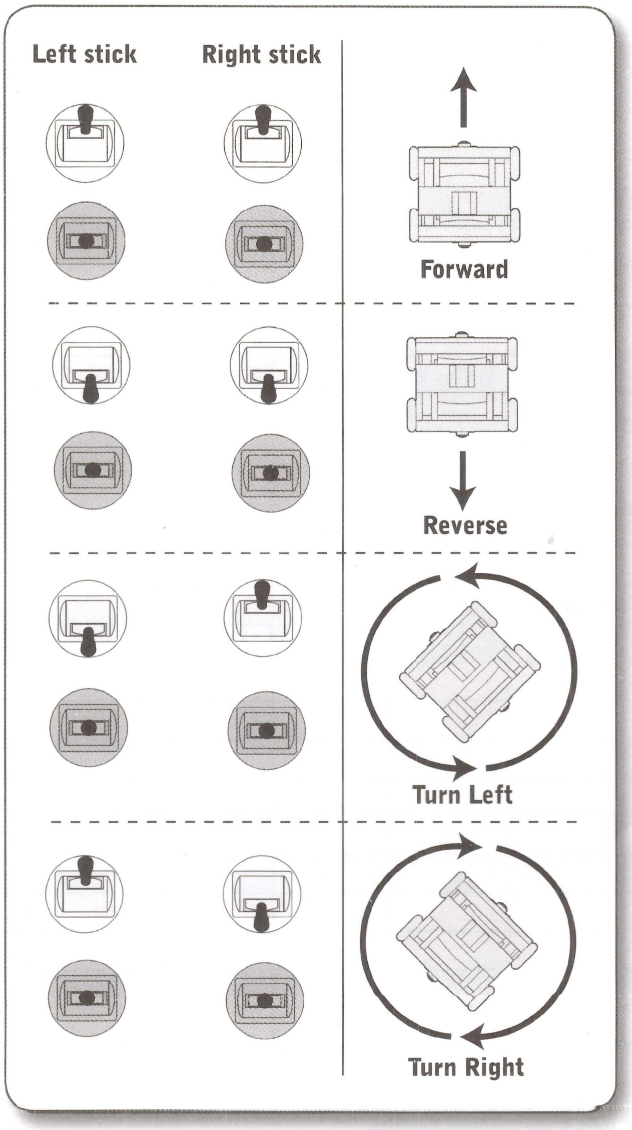
The directions listed in this table indicate the direction of spin for a standard Vex Motor Module. Vex Servo Modules will turn in the opposite direction.

tank-style controls (4WD, two transmitters)

For a 4-motor configuration, the front left motor should plug into Motor Port 3, and the front right motor should plug into Motor Port 2. The rear left motor should go into Motor Port 8, and the rear right motor should go into Motor Port 7. The following controls will then apply.


7
8
2
3
Front
TX
RX
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
ANALOG / DIGITAL
6 CHANNEL FM TRANSMITTER
DRIVE
23
x 2

This configuration is the same as the basic dual-transmitter "23 mode" as far as driving goes, except that pushing the stick on the driver's transmitter causes both motors on the same side to be powered at once rather than just one.


Left stick
Right stick
Forward
Reverse
Turn Left
Turn Right

tank-style controls (4WD, two transmitters), continued

Both transmitters in "23 mode", Jumper 15 set on Micro Controller

CW= clockwise
CCW = counter-clockwise

TRANSMITTER 1

	Motor 1	Motor 2	Motor 3	Motor 4	Motor 5	Motor 6	Motor 7	Motor 8
Channel 1								
Stick Left								
Stick Right								
Channel 2								
Stick Up		CW					CW	
Stick Down		CCW					CCW	
Channel 3								
Stick Up			CCW					CCW
Stick Down			CW					CW
Channel 4								
Stick Left								
Stick Right								
Channel 5								
Top Button								
Bottom Button								
Channel 6								
Top Button								
Bottom Button								

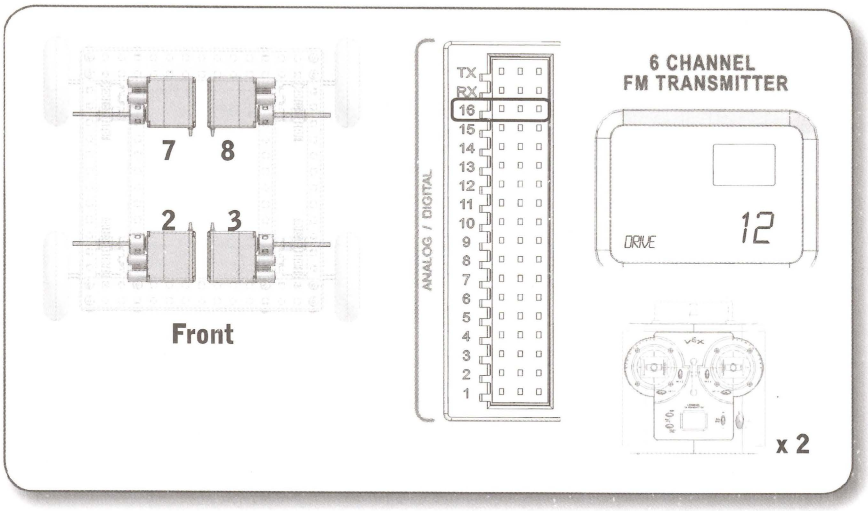
TRANSMITTER 2

	Motor 1	Motor 2	Motor 3	Motor 4	Motor 5	Motor 6	Motor 7	Motor 8
Channel 1								
Stick Left								
Stick Right								
Channel 2								
Stick Up	CW							
Stick Down	CCW							
Channel 3								
Stick Up				CCW				
Stick Down				CW				
Channel 4								
Stick Left								
Stick Right								
Channel 5								
Top Button					CCW			
Bottom Button					CW			
Channel 6								
Top Button						CCW		
Bottom Button						CW		

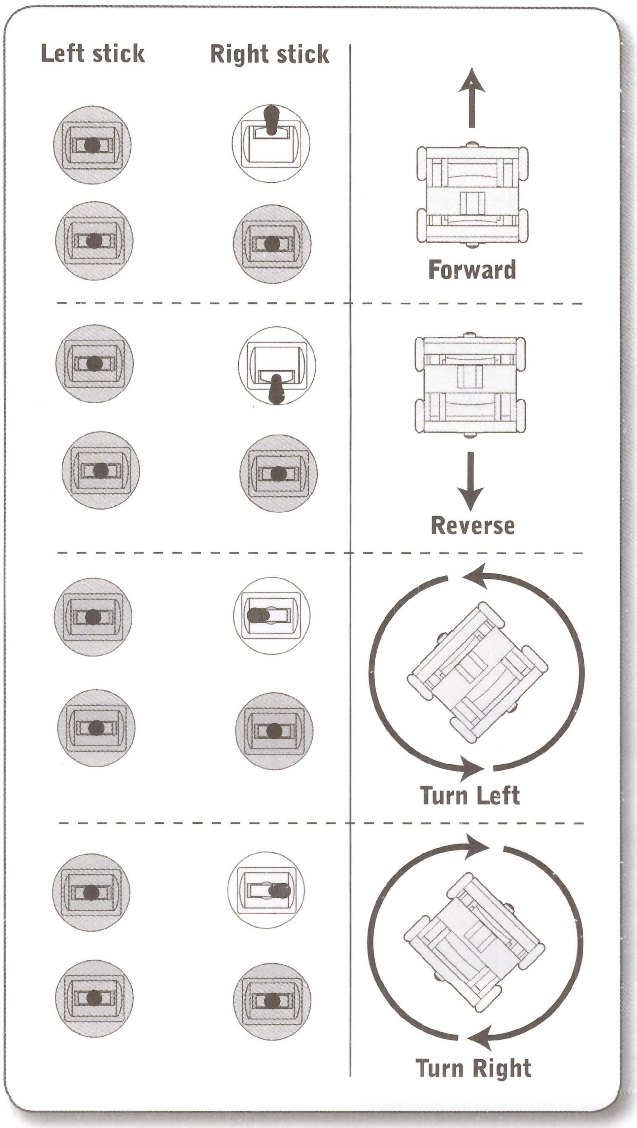
The directions listed in this table indicate the direction of spin for a standard Vex Motor Module. Vex Servo Modules will turn in the opposite direction.

arcade-style controls (4WD, two transmitters)

For a 4-motor configuration, the front left motor should plug into Motor Port 3, and the front right motor should plug into Motor Port 2. The rear left motor should go into Motor Port 8, and the rear right motor should go into Motor Port 7. The following controls will then apply.


7
8
2
3
Front
TX
RX
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
ANALOG / DIGITAL
6 CHANNEL FM TRANSMITTER
DRIVE
12
x 2

This configuration is the same as the basic dual-transmitter "12 mode" as far as driving goes, except that the command mixes from the driver's right-hand stick will drive both motors on the same side at once.


Left stick
Right stick
Forward
Reverse
Turn Left
Turn Right

Note:
"Software 12 mix" ("Jumper 14 mode") cannot be used with dual controllers.

arcade-style controls (4WD, two transmitters), continued

Transmitter 1 in "12 mode", Transmitter 2 in "23 mode", Jumper 16 set on Micro Controller

CW= clockwise
CCW = counter-clockwise

TRANSMITTER 1

	Motor 1	Motor 2	Motor 3	Motor 4	Motor 5	Motor 6	Motor 7	Motor 8
Channel 1								
Stick Left	CW	CW					CW	CW
Stick Right	CCW	CCW					CCW	CCW
Channel 2								
Stick Up	CCW	CW					CW	CCW
Stick Down	CW	CCW					CCW	CW
Channel 3								
Stick Up								
Stick Down								
Channel 4								
Stick Left								
Stick Right								
Channel 5								
Top Button								
Bottom Button								
Channel 6								
Top Button								
Bottom Button								

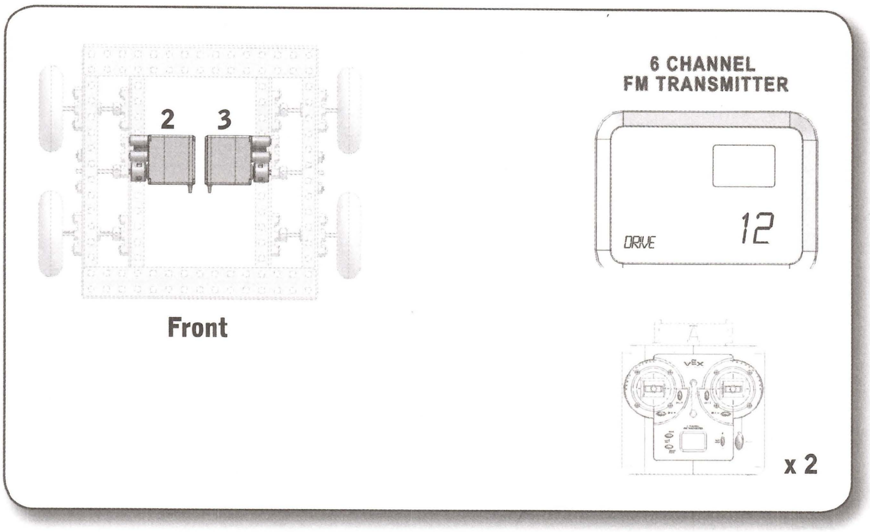
TRANSMITTER 2

	Motor 1	Motor 2	Motor 3	Motor 4	Motor 5	Motor 6	Motor 7	Motor 8
Channel 1								
Stick Left								
Stick Right								
Channel 2								
Stick Up			CW					
Stick Down			CCW					
Channel 3								
Stick Up				CCW				
Stick Down				CW				
Channel 4								
Stick Left								
Stick Right								
Channel 5								
Top Button					CCW			
Bottom Button					CW			
Channel 6								
Top Button						CCW		
Bottom Button						CW		

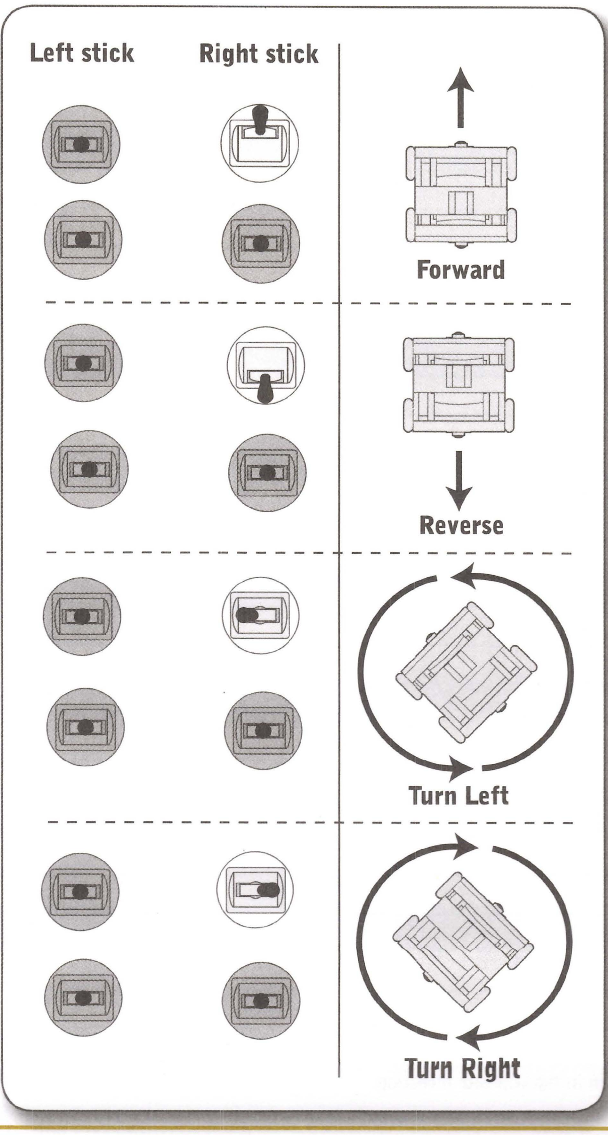
The directions listed in this table indicate the direction of spin for a standard Vex Motor Module.
Vex Servo Modules will turn in the opposite direction.

arcade-style controls (two transmitters)

For a 2-motor configuration, the left motor should plug into Motor Port 1, and the right motor should plug into Motor Port 2. The following controls will then apply.


2
3
Front
6 CHANNEL
FM TRANSMITTER
DRIVE
12
x 2

In this configuration, the first two control channels on the first transmitter are mixed controls that affect both Motor Ports 1 and 2. The second transmitter is used to control some sort of attachment, based on the challenge being attempted. The second transmitter is not placed into "12 mode," as it is designed to work precisely with challenge-based robot attachments by using different sticks (so you can't accidentally affect robot operation by moving the stick on an axis you didn't want—the horizontal axes don't do anything.


Left stick
Right stick
Forward
Reverse
Turn Left
Turn Right

Note:
"Software 12 mix"
("Jumper 14 mode")
cannot be used with
dual controllers.

arcade-style controls (two transmitters), continued

Transmitter 1 in "12 mode", Transmitter 2 in "23 mode", no jumpers set on Micro Controller

CW= clockwise
CCW = counter-clockwise

TRANSMITTER 1

	Motor 1	Motor 2	Motor 3	Motor 4	Motor 5	Motor 6	Motor 7	Motor 8
Channel 1								
Stick Left	CW	CW						
Stick Right	CCW	CCW						
Channel 2								
Stick Up	CCW	CW						
Stick Down	CW	CCW						
Channel 3								
Stick Up			CCW					
Stick Down			CW					
Channel 4								
Stick Left								
Stick Right								
Channel 5								
Top Button				CCW				
Bottom Button				CW				
Channel 6								
Top Button								
Bottom Button								

TRANSMITTER 2

	Motor 1	Motor 2	Motor 3	Motor 4	Motor 5	Motor 6	Motor 7	Motor 8
Channel 1								
Stick Left								
Stick Right								
Channel 2								
Stick Up					CW			
Stick Down					CCW			
Channel 3								
Stick Up						CCW		
Stick Down						CW		
Channel 4								
Stick Left								
Stick Right								
Channel 5								
Top Button							CCW	
Bottom Button							CW	
Channel 6								
Top Button								CCW
Bottom Button								CW

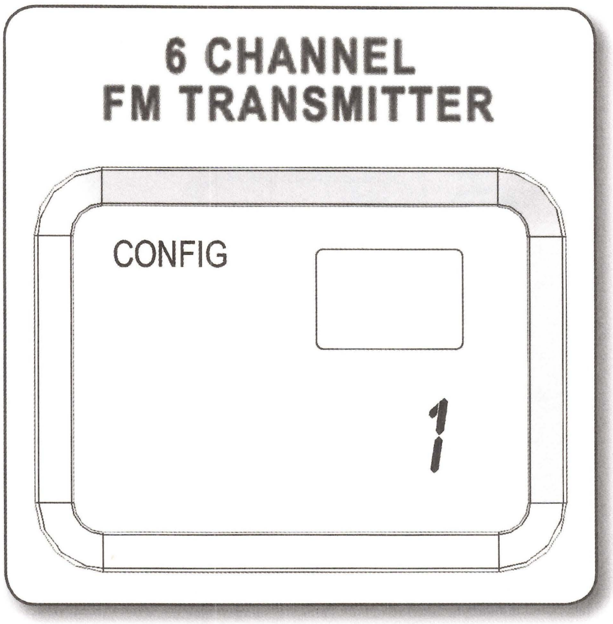
The directions listed in this table indicate the direction of spin for a standard Vex Motor Module. Vex Servo Modules will turn in the opposite direction.

menus

Advanced Transmitter Features

The Transmitter has a large number of onboard options that can help you refine your control over the robot. To access the advanced feature menus, turn on your transmitter, then hold down the Mode and Select buttons together for two seconds until the menus appear.

Config Menu



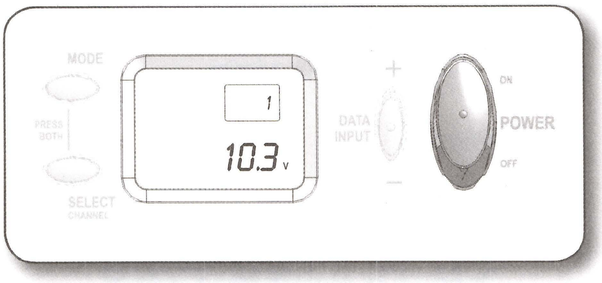
If you design multiple robots or a robot with multiple configurations (removable arm attachments, for example), the Vex Transmitter can store different control settings for each of them. The CONFIG menu allows you to switch between six different control configurations, each of which can be set any way you want for optimal control of a different robot configuration. If you make changes to a configuration and decide later that you would rather restore the defaults for that config, you can also reset them to the factory defaults from this menu.

menus, continued

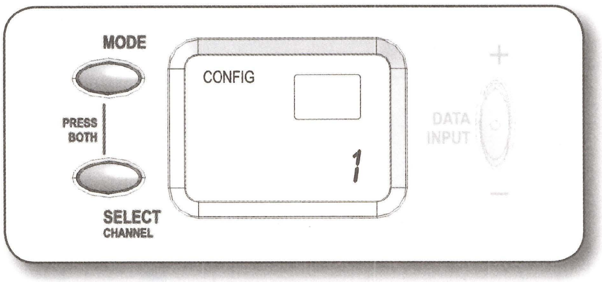
Config Menu, continued

To select a configuration:

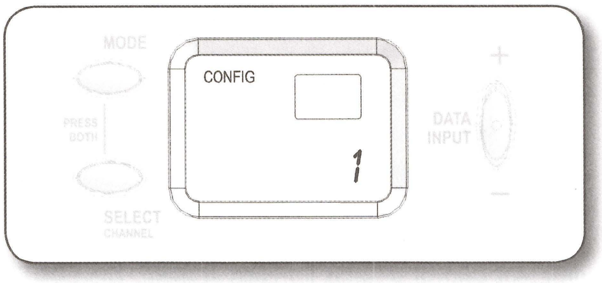
1. Turn on the Transmitter by pushing the power switch to the ON position.


MODE
PRESS BOTH
SELECT CHANNEL
1
10.3 v
DATA INPUT
+
–
ON
POWER
OFF

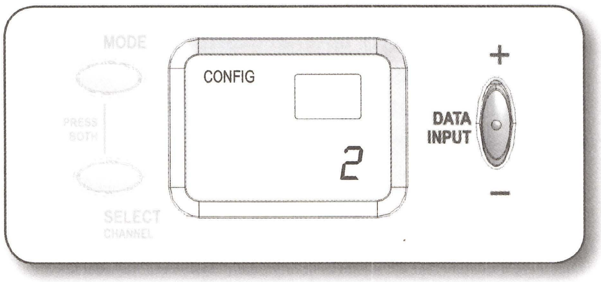
2. Enter the menu on the transmitter by holding down both the Mode and Select buttons next to the display until the menu opens.


MODE
PRESS BOTH
SELECT CHANNEL
CONFIG
1
DATA INPUT
+
–

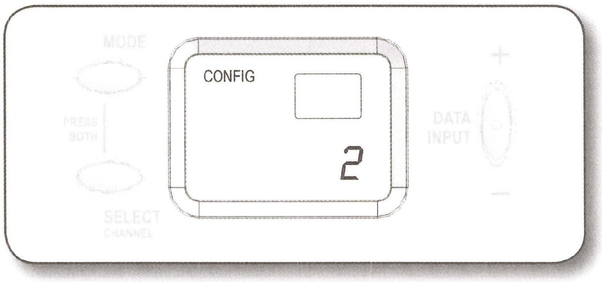
3. CONFIG mode should be open by default. If it is not, then push the Mode button until the word CONFIG appears in the upper-left corner of the display.


MODE
PRESS BOTH
SELECT CHANNEL
CONFIG
1
DATA INPUT
+
–

4. The number in the lower-right indicates which configuration is currently active. Use + and – on the Data Input button to the right of the display screen to change the active configuration.


MODE
PRESS BOTH
SELECT CHANNEL
CONFIG
2
+
DATA INPUT
–

5. Any further programming changes you make in the other menus will now affect the configuration you have chosen. You do not have to confirm your selection with an Enter command.

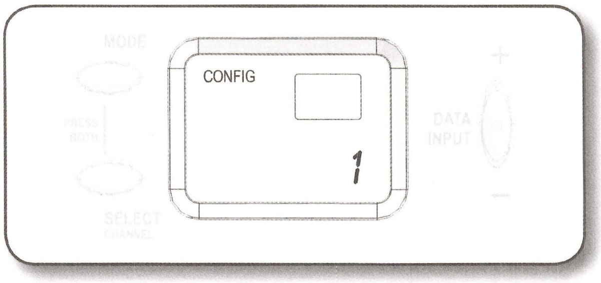

MODE
PRESS BOTH
SELECT CHANNEL
CONFIG
2
DATA INPUT
+
–

menus, continued

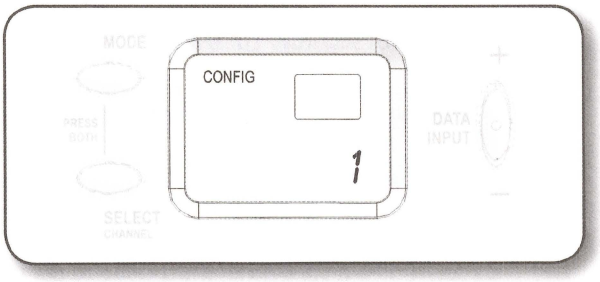
Config Menu, continued

To reset a configuration:

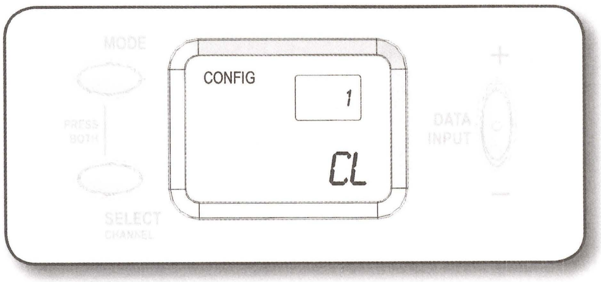
1. Enter the CONFIG menu and select the configuration you wish to reset by following the instructions in the section "To select a configuration" on the previous page.


MODE
PRESS BOTH
SELECT CHANNEL
CONFIG
1
DATA INPUT
+
–

2. Make sure that the number on the screen is the number of the configuration you want to reset.

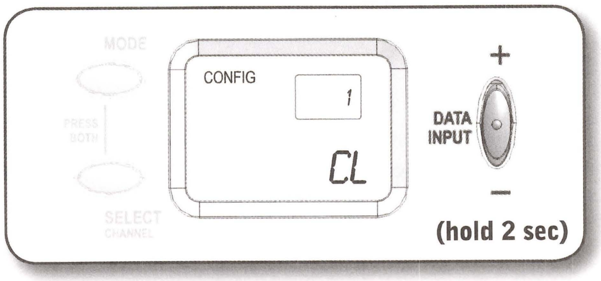

MODE
PRESS BOTH
SELECT CHANNEL
CONFIG
1
DATA INPUT
+
–

3. Press the Select button. The letters CL (for "clear") should appear.


MODE
PRESS BOTH
SELECT CHANNEL
CONFIG
1
CL
DATA INPUT
+
–

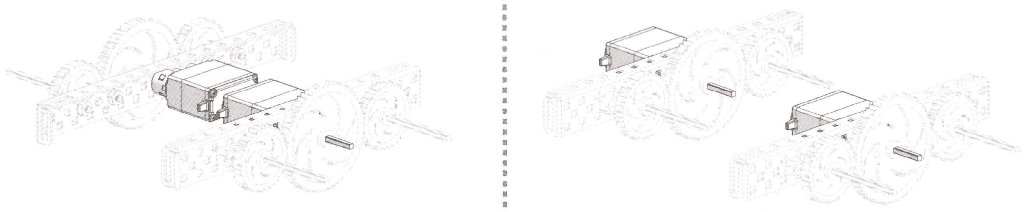
4. Hold either the + or – on the Data Input button for 2 seconds to reset the controls for the selected config number.

The Transmitter will beep twice quickly to indicate that the reset was successful.


MODE
PRESS BOTH
SELECT CHANNEL
CONFIG
1
CL
+
DATA INPUT
–
(hold 2 sec)

menus, continued

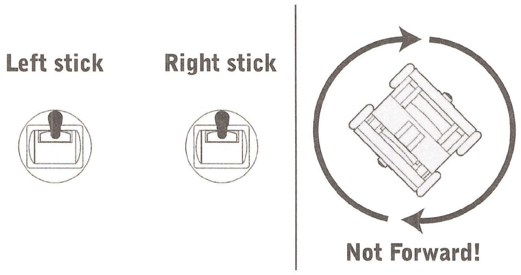
Reverse Menu



Motors Back-to-Back

Motors Side-by-Side

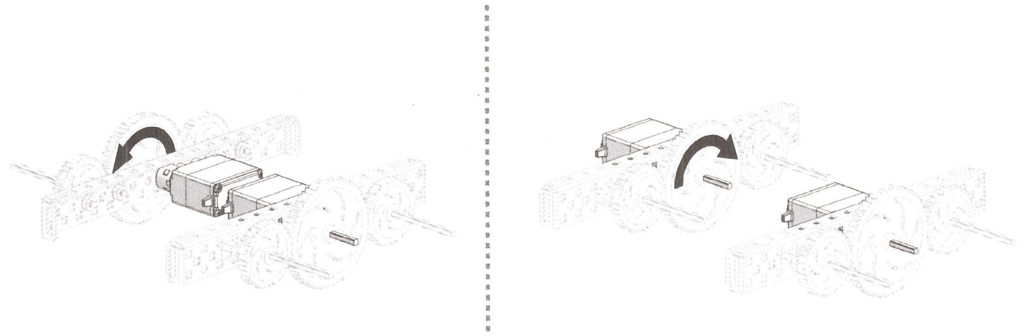
Sometimes, you will want to mount motors in a different orientation than the simple back-to-back configuration used in the Squarebot. Perhaps you would prefer to run the robot using the side-by-side motor configuration shown above. This seems like a straightforward thing to do, but there is a catch.



In a side-by-side configuration, both motors need to spin the same direction in order to make the robot run forward, whereas the back-to-back configuration has the motors spinning in opposite directions to go forward. If you build a robot with the side-by-side configuration shown, the right side will run backwards when you push up on the stick.

menus, continued

Reverse Menu, continued



Motor spins clockwise in both pictures

This is not because of a flaw in the design of the motor or the robot. The "problem" is that the motor is doing the exact same thing it was doing with the back-to-back positioning: it spins clockwise when you push up on the stick, and counterclockwise when you push down. The trouble here is that spinning in the clockwise direction used to equal forward movement in the Squarebot design, but now a clockwise spin equals backward movement for that side of the robot!

There are several ways to fix this problem, like adding an idler gear (see the Motion Subsystem Background Information), but the easiest solution is to change the settings on your transmitter to reverse the commands sent for the joystick axis that controls that motor. The combination of two reversals will give you normal control once again.

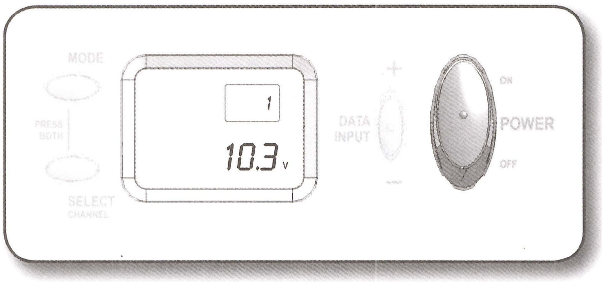
In general, you will find that the controls on the Transmitter are configured for Squarebot-like designs using the back-to-back motor configuration. With the Reverse menu, however, you can reconfigure the controls to support any drive train orientation you may need.

menus, continued

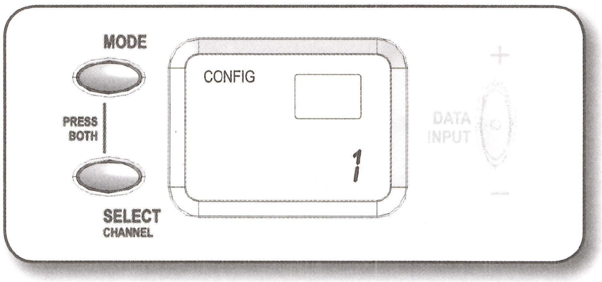
Reverse Menu, continued

To reverse (or un-reverse) an axis:

1. Turn on the Transmitter by pushing the power switch to the ON position.

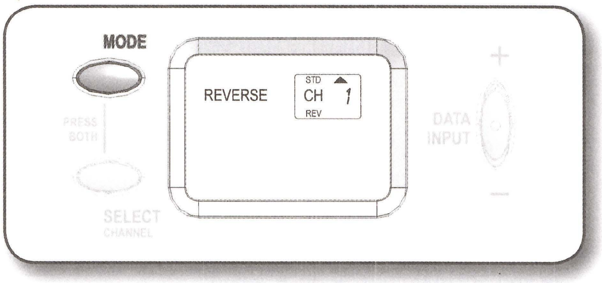

MODE
PRESS BOTH
SELECT CHANNEL
1
10.3 v
+
DATA INPUT
–
ON
POWER
OFF

2. Enter the menu on the transmitter by holding down both the Mode and Select buttons next to the display until the menu opens.

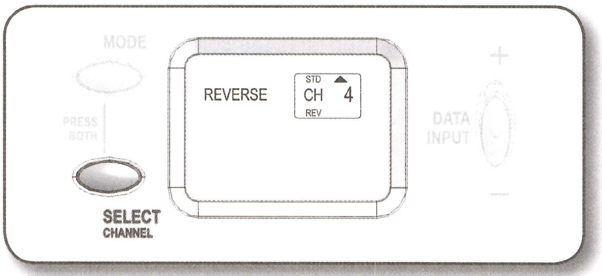

MODE
PRESS BOTH
SELECT CHANNEL
CONFIG
1
+
DATA INPUT
–

3. Push the Mode button until the word REVERSE appears on the left-hand side of the display.

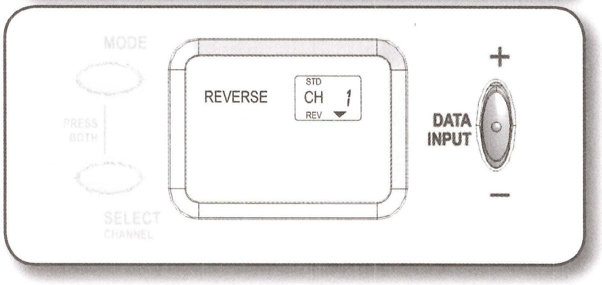
The number in the upper-right indicates which control channel (axis) you are currently viewing. The small arrow to the left of the number indicates whether the axis is currently set to operate with standard (STD) or reversed (REV) directions.


MODE
PRESS BOTH
SELECT CHANNEL
REVERSE
STD
CH 1
REV
+
DATA INPUT
–

4a. Use the Select button to cycle through channels (axes).


MODE
PRESS BOTH
SELECT CHANNEL
REVERSE
STD
CH 4
REV
+
DATA INPUT
–

4b. Use + and – on the Data Input button to the right of the display screen to switch between standard or reversed directional controls for the displayed axis.


MODE
PRESS BOTH
SELECT CHANNEL
REVERSE
STD
CH 1
REV
+
DATA INPUT
–

5. Your changes take effect immediately. You do not have to confirm your selection with an Enter command. You can turn on your robot and test your changes now to see if they have fixed the problem.

menus, continued

Scale Menu

The default controls are often not comfortable for a human operator. Sometimes they feel too sensitive, other times they are not sensitive enough. There are two distinct types of adjustments that can be made in this menu. The first series of adjustments controls the "linear scaling" of the controls, and can be used to make coarse adjustments to the overall range of motion that the transmitter will generate on the motors. The second series of adjustments sets the "exponential scaling" of the controls, which allows you to tweak the controls to make them "softer" or "firmer". These can only be applied to the first two axes (1 and 2, on the right stick), so scaling is only recommended for users of the "12" DRIVE mode (see Basic Transmitter Operation in the Control Subsystem chapter, or Appendix E for full details).

Scale vs. Edit Points

The easiest way to decide whether you want to use SCALE versus EDIT PT to adjust your controls is to first check whether you will need to adjust settings for axes other than 1 or 2. If so, you will need to use EDIT PT, because SCALE can only adjust settings for axes 1 and 2.

After that, it helps to organize your changes into optimizations that are designed to make the robot run better, versus optimizations that are intended to help the human operator. The main strength of the SCALE functions are the exponential controls, which help to give the operator more comfortable response ranges from the joysticks. It makes sense, then, that you should try to use the SCALE menu to help the human operator achieve a comfortable control setup, and the EDIT PT menu for necessary changes to the robot to coordinate better functionality within its own systems (see the EDIT PT section for more information and examples).

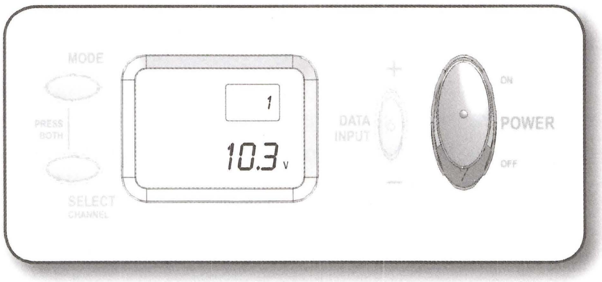
Note: If you plan to use both Scaling and End Points to optimize your robot's performance and control handling, you must adjust the End Points using the EDIT PT menu first. If you change the End Points after you set scaling, the scaling info will also be changed. See the EDIT PT menu section below for details on End Points.

menus, continued

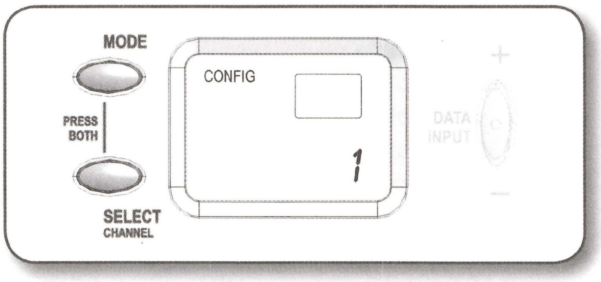
Scale Menu, continued

To adjust linear scaling for an axis:

1. Turn on the Transmitter by pushing the power switch to the ON position.

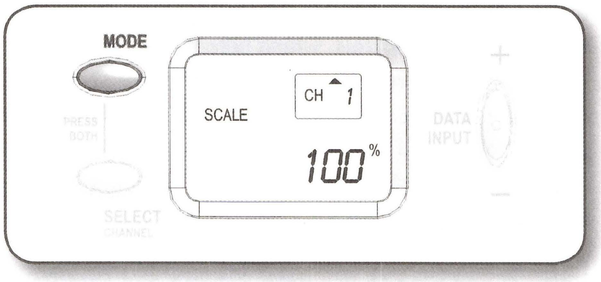

MODE
PRESS BOTH
SELECT CHANNEL
1
10.3 V
+
DATA INPUT
−
ON
POWER
OFF

2. Enter the menu on the transmitter by holding down both the Mode and Select buttons next to the display until the menu opens.

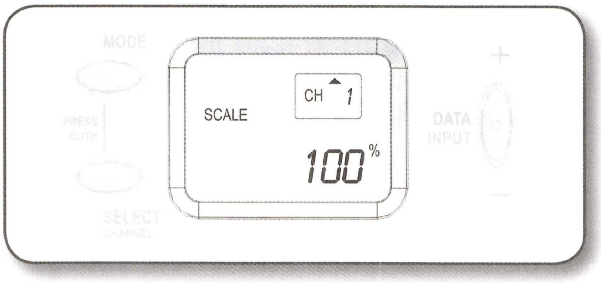

MODE
PRESS BOTH
SELECT CHANNEL
CONFIG
1
+
DATA INPUT
−

3. Push the Mode button until the word SCALE appears on the left-hand side of the display.

The number in the upper-right indicates which control channel (axis) you are currently viewing. The large number in the lower right indicates the current linear scaling value for the displayed channel.


MODE
PRESS BOTH
SELECT CHANNEL
SCALE
CH 1
100%
+
DATA INPUT
−

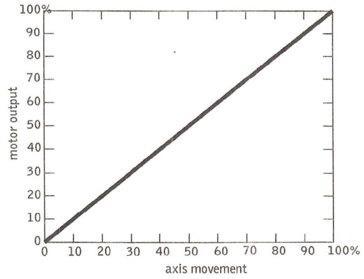
4. Make sure there is no + or – sign in front of the large number in the lower-right. If you see a + or – (or both), you are in the exponential mode, and you should push Select until you see a number without the + or – signs.


MODE
PRESS BOTH
SELECT CHANNEL
SCALE
CH 1
100%
+
DATA INPUT
−

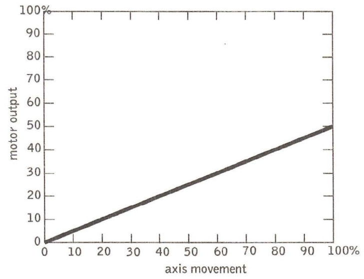
menus, continued

Scale Menu, continued

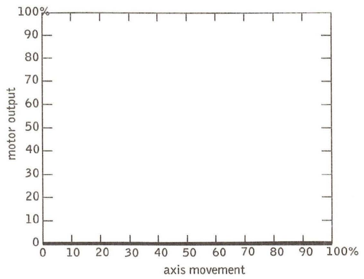
To adjust linear scaling for an axis, continued:



100% Scaling
(Default)

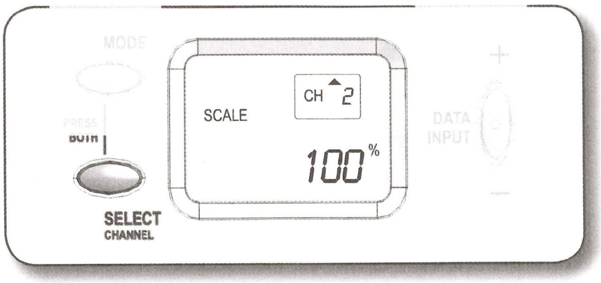


50% Scaling

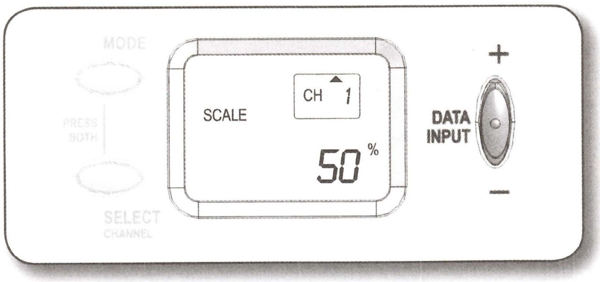


0% Scaling
(Axis Disabled)

5a. Use the Select button to cycle through channels (axes).


MODE
PRESS
BOTH
SELECT
CHANNEL
SCALE
CH 2
100%
DATA
INPUT
+
−

5b. Use + and – on the Data Input button to the right of the display screen to increase or decrease the scaling value for the displayed axis. Higher values (up to the maximum of 100%) cause the motors to move to a fuller extent of their capabilities, while lower values allow you more control, but at the cost of not being able to reach full speed.


MODE
PRESS
BOTH
SELECT
CHANNEL
SCALE
CH 1
50%
DATA
INPUT
+
−

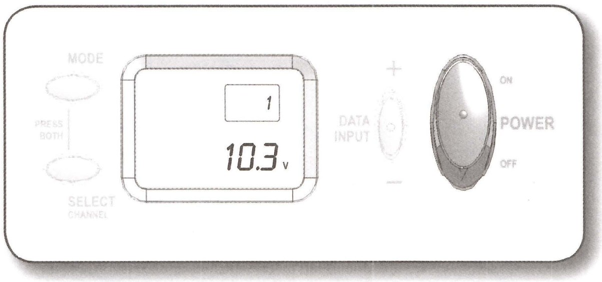
6. Your changes take effect immediately. You do not have to confirm your selection with an Enter command. You can turn on your robot and test your changes now to see if the controls are more comfortable now.

menus, continued

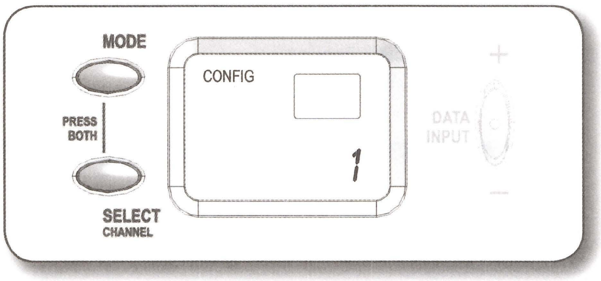
Scale Menu, continued

To adjust exponential scaling for an axis:

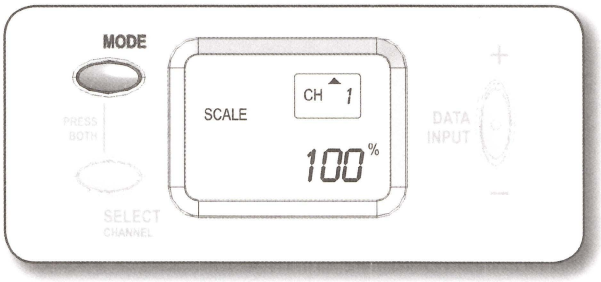
1. Turn on the Transmitter by pushing the power switch to the ON position.


MODE
PRESS BOTH
SELECT CHANNEL
1
10.3 v
+
DATA INPUT
−
ON
POWER
OFF

2. Enter the menu on the transmitter by holding down both the Mode and Select buttons next to the display until the menu opens.

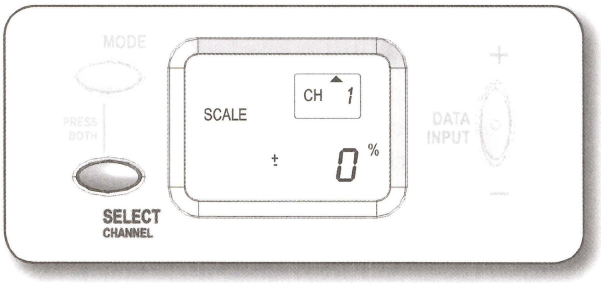

MODE
PRESS BOTH
SELECT CHANNEL
CONFIG
1
+
DATA INPUT
−

3. Push the Mode button until the word SCALE appears on the left-hand side of the display.


MODE
PRESS BOTH
SELECT CHANNEL
SCALE
CH 1
100 %
+
DATA INPUT
−

4. Press the Select button to skip through the Linear Scaling menus, until you see a +/-0% appear.

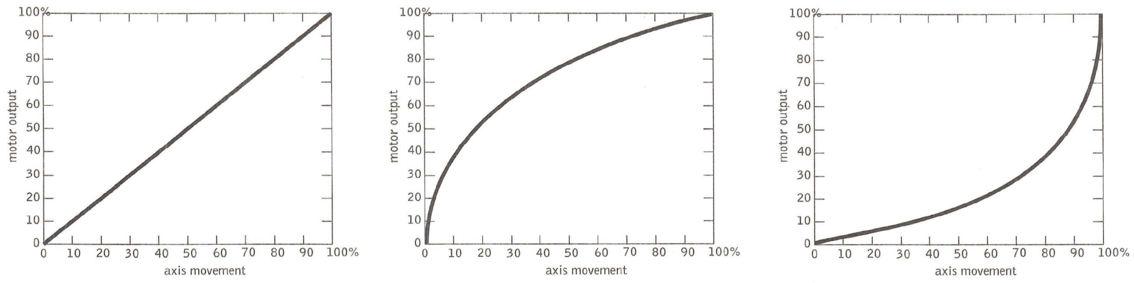
The number in the upper-right indicates which control channel (axis) you are currently viewing. The large number in the lower right indicates the current exponential scaling value for the displayed channel.


MODE
PRESS BOTH
SELECT CHANNEL
SCALE
CH 1
± 0 %
+
DATA INPUT
−

menus, continued

Scale Menu, continued

To adjust exponential scaling for an axis, continued:

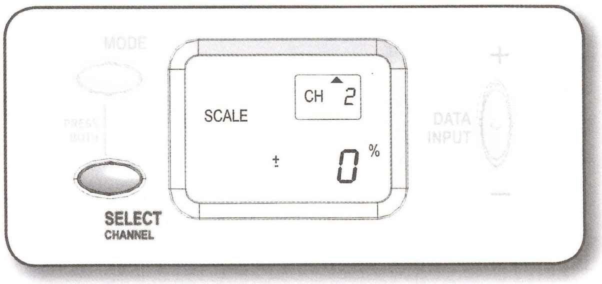


0% Exponential (Default)

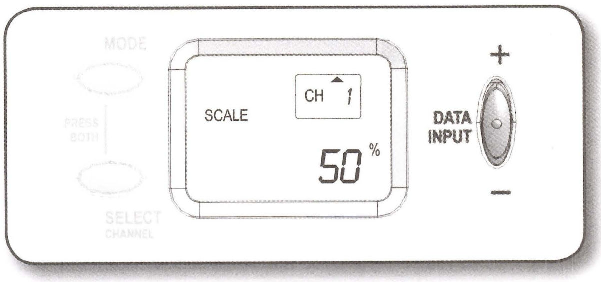
+50% Exponential (tight response)

-50% Exponential (loose response)

5a. Use the Select button to cycle through channels (axes). Be sure you select an option with the + or - sign showing, otherwise you will be adjusting linear scaling rather than exponential.


MODE
PRESS BOTH
SELECT
CHANNEL
SCALE
CH 2
±
0 %
DATA INPUT
+
–

5b. Use + and – on the Data Input button to the right of the display screen to increase or decrease the exponential value for the displayed axis. Higher values make the controls more sensitive to small pushes on the joystick, lower values make the controls "softer" and allow finer control at low motor speeds.

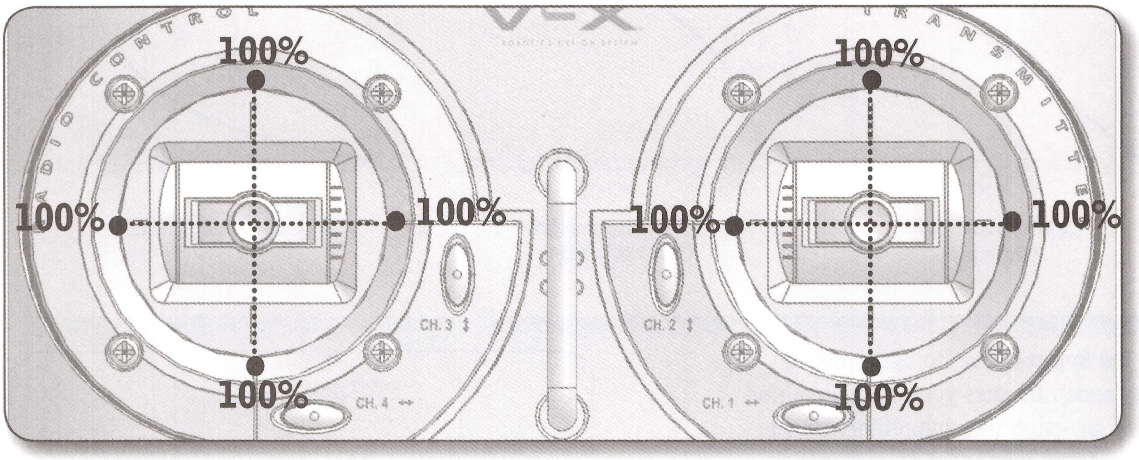

MODE
PRESS BOTH
SELECT
CHANNEL
SCALE
CH 1
50 %
+
DATA
INPUT
–

6. Your changes take effect immediately. You do not have to confirm your selection with an Enter command. You can turn on your robot and test your changes now to see if the controls are more comfortable now.

menus, continued

Edit Points Menu

The primary purpose of EDIT PT mode is to allow small tweaks to optimize the coordination between the Radio Transmitter and the robot's motors. We recommend using EDIT PT to smooth out the interactions between the Transmitter and the motors, and using the SCALE menu to adjust the "feel" of the controls to the human operator's liking.



Compensating for Motor Variance

Not all motors are created equal. At 100% power, no two motors will spin at the exact same speed with the exact same torque, due to tiny variations between individual units in manufacturing. If you order both the left and right motors on the robot to go full power forward, the robot will not travel straight ahead (try it!). Rather, it will go straight and somewhat to one side because one motor will spin faster than the other, causing that side of the robot to get ahead of the slower side.

The solution to this problem is to limit the amount of power that the stronger motor will output at "full stick" (i.e. when the joystick is pushed all the way to the end of its movement range). If the stronger motor were set to output, say, 95% power when its joystick is pushed to full, while the weaker motor runs at 100% when its joystick is at full, the net result would be a robot that moves straight ahead when both sticks are pushed all the way.

The EDIT PT menu allows you to do this by editing the "end point values" of each joystick axis. Setting an end point value to 80%, for instance, would mean that you would only get 80% of a motor's maximum speed when the stick is pushed all the way in that direction.

Furthermore, the EDIT PT menu lets you edit the two endpoints of each axis (up vs. down on the Y-axis, for instance) independently, to account for the fact that a motor will usually not spin with identical power forward and backward either.

These small but significant changes in speed and power can happen any time you make a change to the robot's drive train. You may need to revisit this menu to retune your controls each time you modify your robot.

menus, continued

Edit Points Menu, continued

Compensating for Transmitter Joystick Variance

Ideally, the joystick's physical stopping point at the edge of the controller would match up with the point where it sends its highest power command (either forward or reverse). This is not always the case, due to manufacturing variance, and sometimes the maximum power point actually resides under the plastic cover, out of reach of the joystick.

EDIT PT allows you to set values "above 100%" power (up to 120%) in order to coax out this little bit of extra signal range from your Transmitter. Setting the endpoint past 100% doesn't actually make the motors run faster than 100%. Instead, it makes the joystick behave as if the 100% point were closer to the center than the actual edge of the device. Since the "electrical endpoint" may be outside the physical range, this lets you move the 100% power point back into the joystick's physical reach.

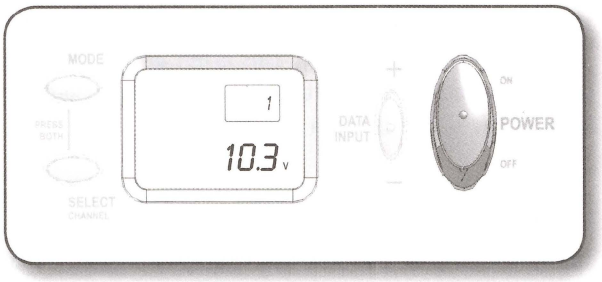
Pushing the joytsick past the 100% point (if you move the 100% point too far in) will result in a 100% power signal being sent.

menus, continued

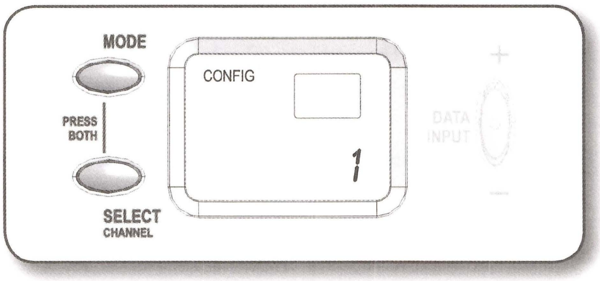
Edit Points Menu, continued

To adjust an end point:

1. Turn on the Transmitter by pushing the power switch to the ON position.

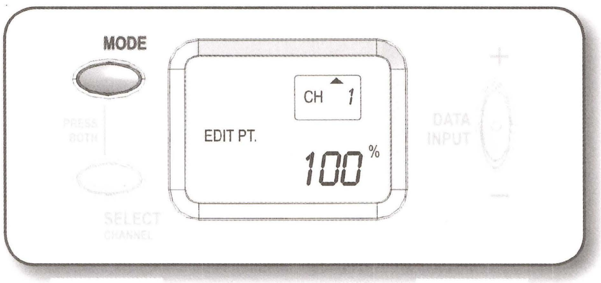

MODE
PRESS BOTH
SELECT CHANNEL
1
10.3 V
+
DATA INPUT
-
ON
POWER
OFF

2. Enter the menu on the transmitter by holding down both the Mode and Select buttons next to the display until the menu opens.


MODE
PRESS BOTH
SELECT CHANNEL
CONFIG
1
DATA INPUT

3. Push the Mode button until EDIT PT appears on the left-hand side of the display.

The number in the upper-right indicates which control channel (axis) you are currently viewing. The small arrow to the left of the number indicates which half of the axis you are modifying the end point for. The large number in the lower right indicates the current end point power value for that direction of the displayed channel.

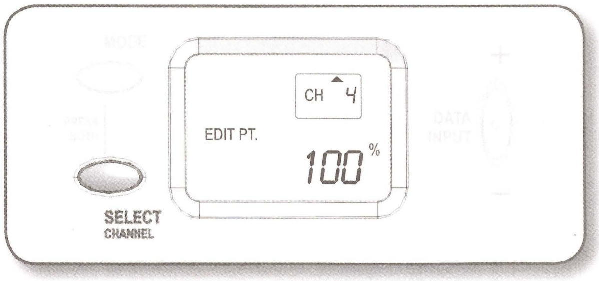

MODE
PRESS BOTH
SELECT CHANNEL
CH 1
EDIT PT.
100 %
DATA INPUT

menus, continued

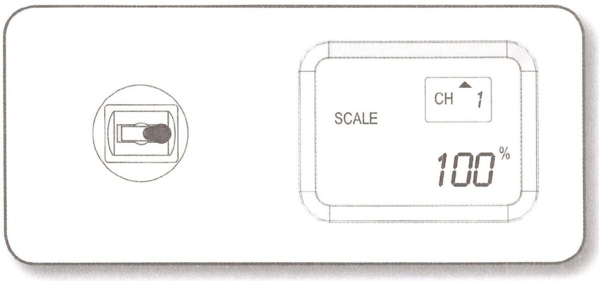
Edit Points Menu, continued

To adjust an end point, continued:

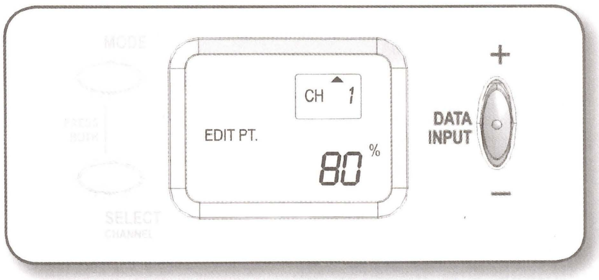
4a. Use the Select button to cycle through channels (axes).



4b. Every axis has two end points (one for each direction the stick can go from center along that axis). Push the stick toward the end point for the selected channel you want to adjust.



4c. Use + and – on the Data Input button to the right of the display screen to increase or decrease the end point (maximum power) for the displayed half of the axis. You cannot go below 70% or above 120% of the default amount. Consider revising your design or checking your components for possible malfunction if you need more adjustment than this range provides.



5. Your changes take effect immediately. You do not have to confirm your selection with an Enter command. You can turn on your robot and test your changes now to see if they improved your robot's performance.

menus, continued

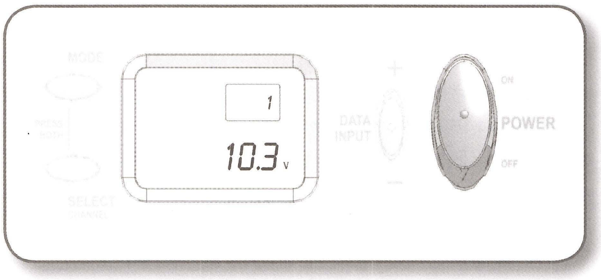
Trim Menu

Generally, you will not need to visit the TRIM menu much, because you can center ("trim") the joysticks using the channel trim buttons located directly on the controller.

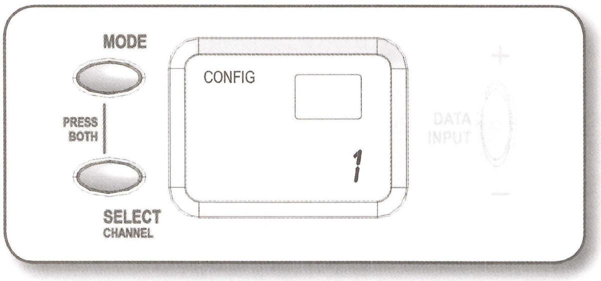
However, the trim buttons make adjustments in increments of 5 trim units, and sometimes you need to make finer changes. In those cases, you can use the TRIM menu to change the trim settings one point at a time.

To make fine adjustments to the sticks:

1. Turn on the Transmitter by pushing the power switch to the ON position.

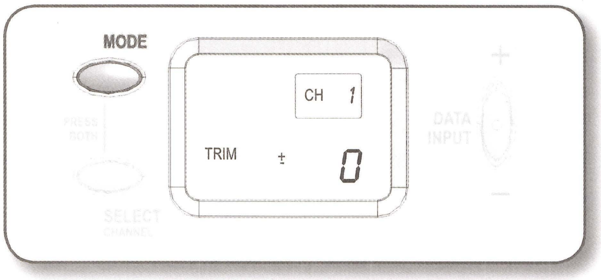

MODE
1
10.3 v
DATA INPUT
+
-
ON
POWER
OFF
SELECT CHANNEL

2. Enter the menu on the transmitter by holding down both the Mode and Select buttons next to the display until the menu opens.


MODE
PRESS BOTH
SELECT
CHANNEL
CONFIG
1
DATA INPUT
+
-

3. Push the Mode button until TRIM appears on the left-hand side of the display.

The number in the upper-right indicates which control channel (axis) you are currently viewing. The large number in the lower right indicates the current amount of trim for the displayed channel.

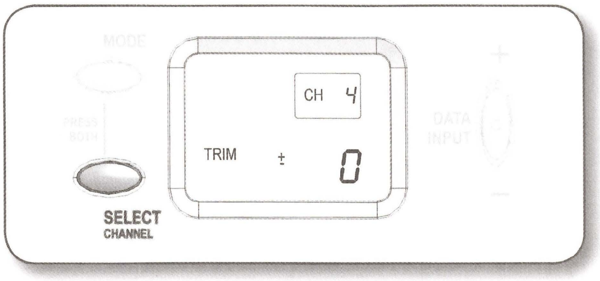

MODE
PRESS BOTH
SELECT CHANNEL
CH 1
TRIM ± 0
DATA INPUT
+
-

menus, continued

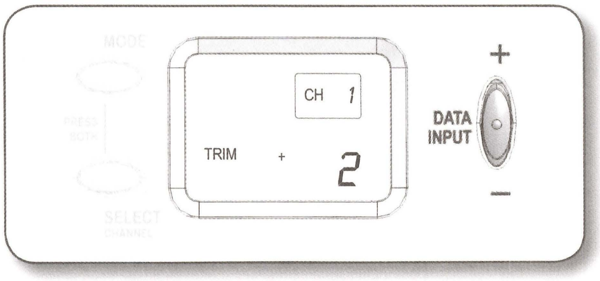
Trim Menu, continued

To make fine adjustments to the sticks, continued:

4a. Use the Select button to cycle through channels (axes).


MODE
PRESS BOTH
SELECT
CHANNEL
CH 4
TRIM
±
0
DATA INPUT
+
–

b. Use + and – on the Data Input button to the right of the display screen to make adjustments to the amount of trim being applied to that axis. This will allow you to adjust the "center" point on the stick until it matches with the actual stick. See also "Controller Trim" in the Radio Subsystem chapter.


MODE
PRESS BOTH
SELECT
CHANNEL
CH 1
TRIM
+
2
DATA INPUT
+
–

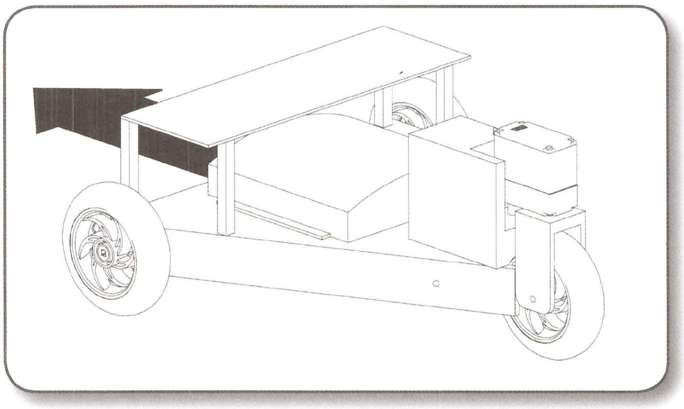
5. Your changes take effect immediately. You do not have to confirm your selection with an Enter command. You can turn on your robot and test your changes now to see if they have fixed the problem.

menus, continued

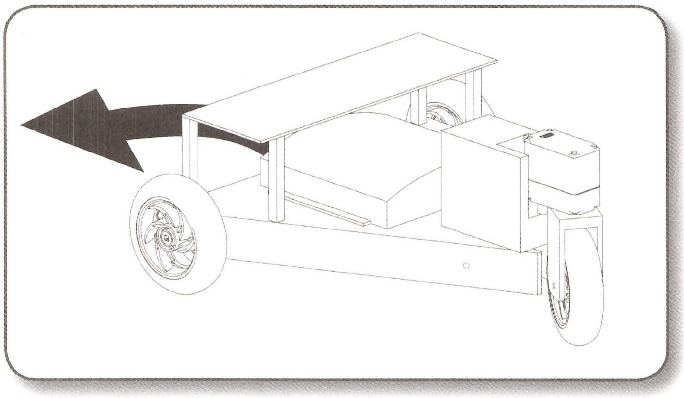
Programmable Mix Menu

P.Mix is short for Programmable Control Mixer. This menu allows you to program one axis "mix" into your controls, so that moving a single joystick axis can control more than one output channel.

In a Programmed Mix, there are three components: the master channel, the slave channel, and the mixing rate. The relationship is simple: the slave channel gets a portion of the master channel's distance-from-center value added to it. The portion is the mixing rate.



You may want to do this, for instance, if you construct a three-wheeled robot with a steerable back wheel, and want to drive it using the arcade-style controls (see Basic Transmitter Operation in the Control Subsystem chapter). As you turn left or right, you want the rear wheel to assist in turning by turning to face slightly in the direction opposite the turn.



In order to do this, you need the servomotor controlling the direction of the rear wheel to turn in conjunction with the left or right turning commands on the joystick.

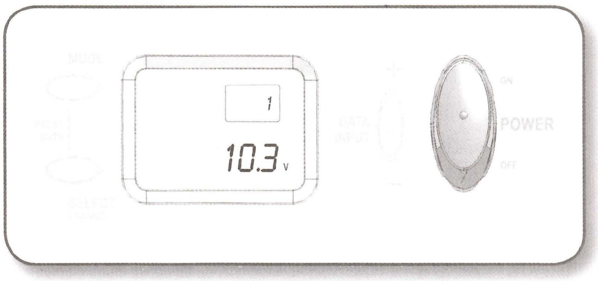
A Programmable Mix can do this:
Master Ch.1, Slave Ch.3, Rate -80% = Pushing the stick left causes the two driving wheels to turn as they normally would for the amount you push, but the servomotor on channel 3 will turn to the right (because the direction is reversed by the – sign) as if you had pushed the channel 3 stick 80% of that distance, thus assisting the robot in its turn.

menus, continued

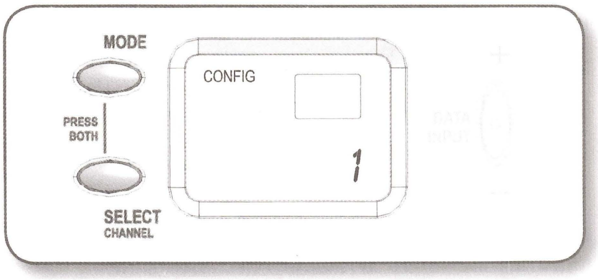
Programmable Mix Menu, continued

To set up the Programmable Mix:

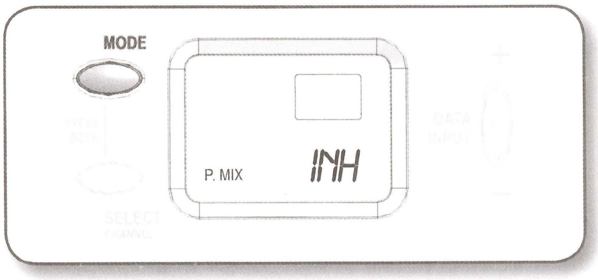
1. Turn on the Transmitter by pushing the power switch to the ON position.


1
10.3 v
ON
POWER
OFF

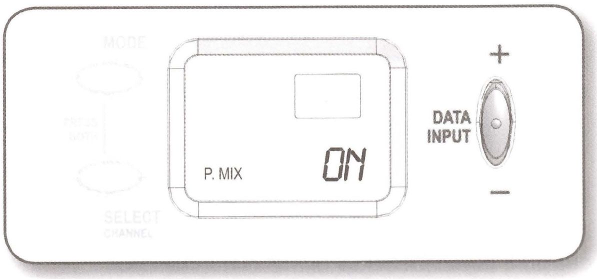
2. Enter the menu on the transmitter by holding down both the Mode and Select buttons next to the display until the menu opens.


MODE
CONFIG
PRESS BOTH
1
SELECT
CHANNEL

3. Push the Mode button until P.MIX appears in the lower-left part of the display.


MODE
P. MIX
INH

4. The Programmable Mixer mode will read "Inh" ("Inhibited") if it is disabled, or "on" if it is enabled. Press either + or – on the Data Input button to change it to "on" if it is not already on.


+
DATA INPUT
−
P. MIX
ON

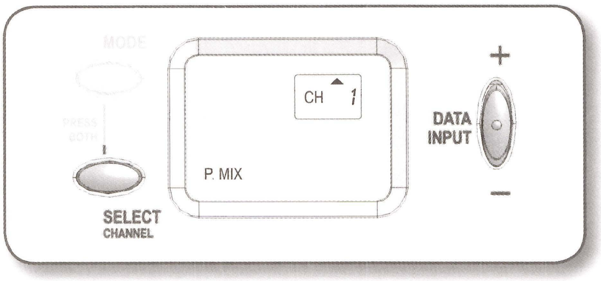
menus, continued

Programmable Mix Menu, continued

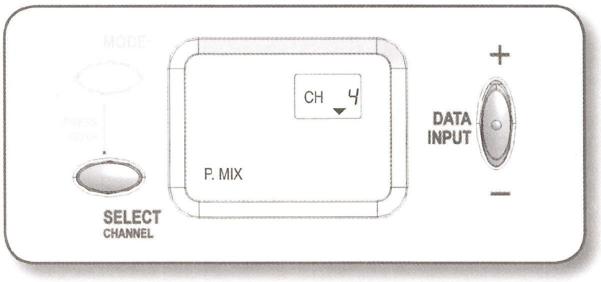
To set up the Programmable Mix, continued:

Select a Master Channel, a Slave Channel, and a Mix Rate. The arrow in the upper-right corner indicates which of the three you are setting. When the arrow faces upward, you are selecting a Master Channel. When the arrow points downward, you are selecting the Slave Channel. When there is no arrow, but a large number and % sign appear in the lower-right, you are selecting the Mix Rate.

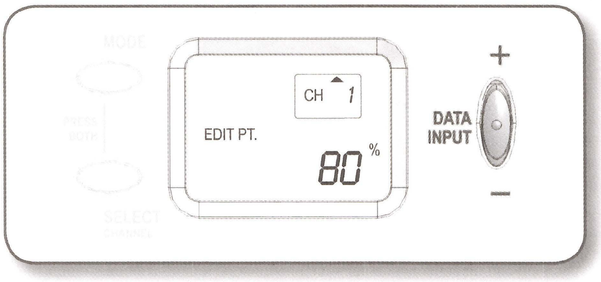
5a. Set the Master Channel by pressing Select until the upward arrow appears next to the channel number in the upper right part of the display. Change the Master Channel number by pressing the + or – on the Data Input button.



5b. Set the Slave Channel by pressing Select until the downward arrow appears next to the channel number (it should only take one press from the Master Channel screen). Change the Slave Channel number by pressing the + or – on the Data Input button.



5c. Set the Mix Rate by pressing Select until the large number and % sign appear in the lower right (two presses from the Slave Channel screen). Press or hold the + side of the Data Input button to increase the mix rate; press or hold the – side of the Data Input button to decrease the mix rate.



Numbers above 0 will make the slave channel move in the same direction as the master channel; numbers below 0 will make the slave channel move in the opposite direction.

6. Your changes take effect immediately. You do not have to confirm your selection with an Enter command. You can turn on your robot and test your changes now to see if the controls are working the way you want them to now.

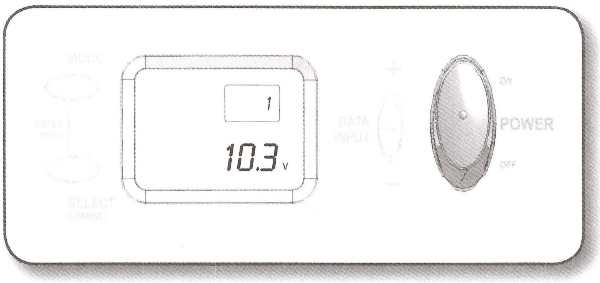
menus, continued

Driving Mode Menu

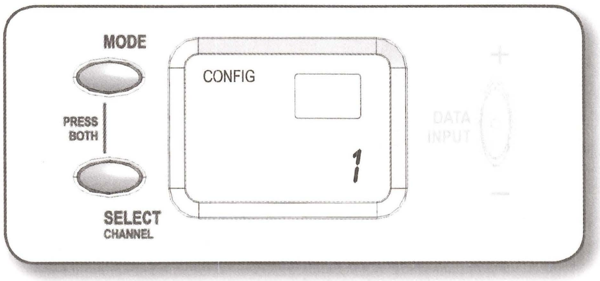
The DRIVE menu allows you to select your driving mode. By default, each axis of the Transmitter controls one motor port on the Micro Controller (this is called "23" mode, because the main motors are controlled by axes 2 and 3). You can change this to "12" driving mode where the right joystick (axes 1 and 2 = "12") controls both forward/back and turning motion.

To change driving control modes:

1. Turn on the Transmitter by pushing the power switch to the ON position.

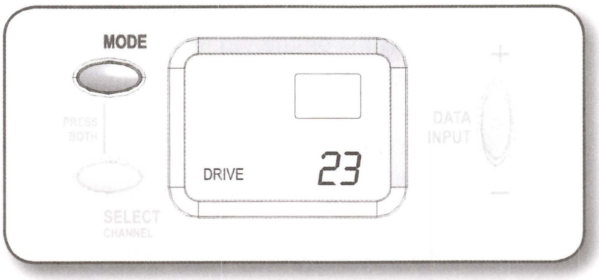

MODE
PRESS BOTH
SELECT CHANNEL
1
10.3 v
+
DATA INPUT
–
ON
POWER
OFF

2. Enter the menu on the transmitter by holding down both the Mode and Select buttons next to the display until the menu opens.

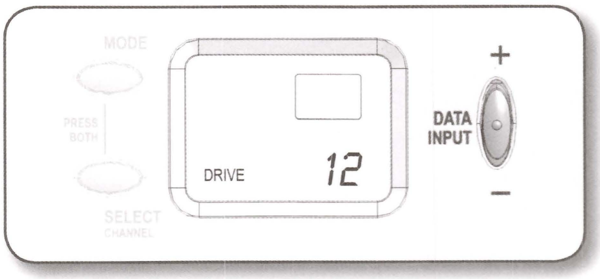

MODE
PRESS BOTH
SELECT CHANNEL
CONFIG
1
+
DATA INPUT
–

3. Enter DRIVE mode by pressing the Mode button until DRIVE is displayed on the left side (it's the last mode).

The current driving mode is displayed. This will be either "23" or "12".


MODE
PRESS BOTH
SELECT CHANNEL
DRIVE
23
+
DATA INPUT
–

4. Press the + or – on the data input button on the right side of the display to switch between these two modes. For more information on the difference between "23" and "12" modes, see Basic Controller Operation in the Control Subsystem chapter, or consult Appendix E for complete control information.


MODE
PRESS BOTH
SELECT CHANNEL
DRIVE
12
+
DATA INPUT
–

5. Your changes take effect immediately. You do not have to confirm your selection with an Enter command. You can turn on your robot and test your changes now to see if the controls are working the way you want them to now.

menus, continued

Driving Mode Menu, continued

Additional Notes on Driving Modes:
"23 mode" is the equivalent of having every joystick axis send its signal directly to the motor on the same-numbered port on the Robot Controller. This is the mode you may want to stick with if you are controlling a design where control of individual motor ports is important.

"12 mode" is actually a "mix" mode, where the output commands sent to ports 1 and 2 do not represent the input from a single joystick axis. The actual equations used are:

Motor Port 1 = 50% of stick 1 + 50% of stick 2
Motor Port 2 = 50% of stick 2 – 50% of stick 1

As you can see, this automatically allows you to go to the 100% motor power if you push the stick to the corners. However, it also means that the robot will only move at 50% of maximum motor power straight forward (stick axis 2 at max * 50%, and no contribution from stick axis 1).

Extra info about mixes and the DRIV 12 mode:
Motor Port 1 = 50% of stick 1 + 50% of stick 2
= 50% * (stick 1 + 100% of stick 2)

Motor Port 2 = 50% of stick 2 – 50% of stick 1
= 50% * (stick 2 – 100% of stick 1)

You can think of this as a pair of "mixes", as if you had set them in the P.Mix section (although P.Mix on the Vex Transmitter only allows one mix, so you could not quite duplicate this functionality through the P.Mix mode here). Channel 1 would have a -100% mix on Channel 2, and Channel 2 would have a +100% mix on Channel 1; both axes would then be scaled to 50% as if you had set that option in the SCALE menu.